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Pope-Reid Associates, Inc., St. Paul, MN

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GUIDANCE MANUAL: COST ESTIMATES FOR CLOSURE AND POST-CLOSURE PLANS (40CFR PARTS G AND H)

VOLUME I - TREATMENT AND STORAGE FACILITIES

Prepared for:

U. S. Environmental Protection Agency
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This volume is intended for use by hazardous waste facility owners/operators who prepare closure and post-closure cost estimates for treatment, storage, and incineration facilities and by regulatory officials who review these cost estimates for 40 CFR Parts 264 and 265 Subpart H. This volume's purpose is to provide a framework for developing the closure cost estimate for treatment and storage units (contains, tanks), and incinerators.

This volume contains worksheets for estimating closure costs for treatment/storage units as well as summary worksheets for totalling facility costs. Fore those cases where tank facilities must also prepare most-closure estimates, post-closure estimates, post-closure worksheets are also provided in this volume.

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CHAPTER 1

INTRODUCTION

This is Volume III of the Guidance Manual: Cost Estimates for Closure and Post-Closure Plans (Subparts G and H). This volume contains information and guidance on unit cost ranges, typical unit costs, and how the unit costs are applied in various facility situations. The purpose of this volume is to provide guidance to the user in completing the worksheets in Volumes I and II. Prior to using this volume, the user should review the closure and post-closure worksheets, and based on the review of the closure and post-closure plans, determine the applicable closure and post-closure items which need to have cost estimates developed. For those items which the user is having difficulty in developing the cost estimate, the user should refer to the appropriate pages in this volume which are referenced on the worksheets.

The unit costs presented in this volume were developed from cost information obtained through cost estimating manuals, EPA reports, technical publications, contractors' bid estimates, equipment vendor specifications and contacts, and site surveys. All costs are in 1986 dollars and are for third-party costs.

1.1 DESCRIPTION OF THE COST ESTIMATING PROCESS

This section provides a brief description of the methodology employed in this document to develop reasonable unit cost estimates for the variety of activities encountered during facility closure and post-closure. The steps involved in removing contaminated soils at a waste pile site and the selection of unit costs to excavate this material are used to illustrate the cost estimating process.

The first step in the cost estimating process is to list the specific activities to be performed by the site contractor in accomplishing a particular task. Once these activities (or subtasks) are defined, the labor and equipment

requirements and the corresponding unit costs for each component can be determined. The subtasks associated with contaminated soil removal and management are:

- conduct soil sampling and analysis to determine the extent of contamination and degree of health risk;
- evaluate site and soil characteristics to determine if any unusual or adverse conditions exist;
- select heavy equipment to excavate soil and haul it to a disposal site;
- transport materials over a specified distance and dispose at a commercial hazardous waste facility; and
- decontaminate heavy equipment following excavation and transport.

The next step is to select the appropriate unit costs. For this example, unit cost selection for excavating contaminated soil will be described.

On the basis of the results of the soil analysis, the area and depth of soil to be exhumed are determined. Information on the type of contaminant(s) and degree of risk to worker health and safety can also be assessed from the analytical results. This will help to estimate the type of protective clothing and safety equipment needed by the excavating team and the amount of surcharge added by the site contractor to handle hazardous materials. Also, by determining the quantity and depth of soil contamination, the appropriate excavating equipment can be selected.

The unit cost for excavation varies by equipment type, equipment capacity, and soil and site conditions encountered. Front-end loaders (both wheel and tracktype) can be used for very shallow excavations only and usually are combined with a dozer to provide loading. Likewise, front shovels are used for shallow digging over a large area (as in quarries) but are not capable of deep excavations. The most appropriate equipment type for excavation of contaminated soils is the backhoe (also known as a hydraulic excavator). Backhoes are capable of excavating to depths of up to 30 feet (depending on machine size) and have common bucket capacity ratings of one-half to four cubic yards.

For estimating the cost of soil excavation with a backhoe, a unit cost reference such as Means Site Work Cost Data, published annually by R.S. Means Company, Inc., provides reasonably accurate unit costs for a wide variety of site work activities under normal site conditions. Increased precision in the unit cost estimate can be gained with site-specific information such as soil type, moisture conditions, and required excavation depths when using this and other cost references. For this example, we will assume that a medium soil type will be excavated and loaded into trucks with a 1½ cubic yard capacity backhoe at a cost of $2.26 per cubic yard.

The range of unit costs for backhoe excavation in medium earth presented in Means is $1.67 to $4.60 per cubic yard. If soft soil or sand is to be excavated, 15 percent could be deducted from the unit cost of medium earth excavation. On the other hand, if heavy soil or clay is anticipated, a 60 percent increase in this unit cost would be necessary to account for decreased equipment efficiency. In addition, if excavation in wet conditions is expected (because of a high groundwater table or heavy rains, for example), at least 50 percent should be added to the unit cost for excavation.

The total cost for excavating the contaminated soil at the site is not, however, simply the unit cost of $2.26 per cubic yard times the quantity of soil to be excavated. It is also necessary to add costs for equipment mobilization and demobilization, protective clothing and equipment, and a surcharge for handling hazardous materials. Mobilization/demobilization costs, which account for equipment delivery, set-up, break-down, and return, vary by equipment size (i.e., greater cost for larger equipment) and can also be estimated using Means. The cost for mobilization/demobilization of a 1½ cubic yard backhoe is $230.

Based on the results of the soil analysis conducted prior to excavating, the type and concentration of contaminants will be known and the degree of worker health risk can be estimated. This information is then used by the engineer and site contractor to select protective clothing and safety equipment for site personnel and to establish a surcharge for excavating the hazardous soils.

Costs for protective clothing and safety equipment such as respirators can e estimated using laboratory supply catalogs such as Safety Equipment and Supplies, published by Lab Safety Supply Company. Cost estimates for personnel protection in hazardous environments vary significantly, depending on the sensitivity of the skin and respiratory system to the hazardous materials being handled. At a minimum, a cost of $77 per person is recommended and includes disposable coveralls, gloves, goggles, hard hat, and a half-mask respirator.

Finally, a surcharge is often added by the site contractor either to the unit cost of excavation (i.e., to the cost per cubic yard) or to the total job cost to account for increased insurance (liability and medical) premiums, higher wages for personnel, equipment modifications, safety equipment, and personnel training. A surcharge will usually add 75 to 150 percent to the cost of normal excavation activities,[1] depending on the degree of hazard existing at the site. We estimate a typical surcharge for contaminated material excavation to add 100 percent to the base cost of excavation.

The total cost of excavating contaminated soils under the assumptions provided in this example can now be estimated. The following cost components are known:

- mobilization/demobilization of backhoe is $230;
- excavation is $2.26/yd^3; a 100 percent surcharge is applied to the unit cost of excavation so the new cost is $4.52/yd^3;
- the cost for protective clothing is estimated at $77/person times the number of site personnel present (normally two--an operator and a laborer).

A similar procedure is followed for the preparation of other closure or post-closure activity costs.

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[1]The Hazardous Waste Consultant, Volume 2 - Issue 3, May/June 1984, "Costs for Worker Health and Safety Add Significantly to Hazardous Waste Cleanup Costs," SCS Engineers, p. 1-2.

In summary, the cost estimating process consists of identifying the subtasks to be performed, selecting the appropriate labor and equipment to accomplish each subtask, and using a cost reference such as Means to select a unit cost for each of the site work components identified in the subtasks.

CHAPTER 2

MONITORING AND TESTING

The Part 264 and Part 265 regulations of 40 CFR require various types of monitoring and testing at treatment, storage, and disposal facilities during the closure and post-closure care periods. This chapter presents the unit costs and assumptions used in developing costs for the following: groundwater quality monitoring, groundwater contamination monitoring, primary drinking water parameters monitoring, groundwater detection monitoring, groundwater compliance monitoring, soil core monitoring, soil-pore liquid monitoring, testing for contaminated soil, gas monitoring at landfill facilities, and air quality monitoring during incineration.

2.1 GROUNDWATER MONITORING

Sections 264.90 and 265.90 of 40 CFR require that facilities with groundwater monitoring systems continue monitoring the groundwater during closure and the post-closure care period. If a tank facility is closed as a landfill, groundwater monitoring wells will have to be constructed during the closure period, and initial background concentrations established before groundwater monitoring can continue. This section contains the unit costs for groundwater monitoring.

2.1.1 Regulatory Requirements

Section 265.91 requires a minimum of four groundwater monitoring wells, at least one well hydraulically upgradient and at least three wells hydraulically downgradient of the waste management area. Section 265.92 requires that two types of groundwater sampling and analysis be conducted during closure and the post-closure care period: groundwater quality and groundwater contamination.

Groundwater quality sampling and analysis consist of determining the concentration of each of the following parameters in the groundwater at each monitoring well: chloride, iron, manganese, phenols, sodium, and sulfate. Section 265.92(d) specifies that groundwater quality sampling and analysis must be conducted at least annually.

Groundwater contamination sampling and analysis consist of determining the concentration or value of each of the following indicator parameters in the groundwater at each monitoring well: pH, specific conductance, total organic carbon, and total organic halogen. Because groundwater contamination data are to be evaluated statistically, each determination of the concentration or value of an indicator parameter in the groundwater sample must be based on a minimum of four replicate measurements. Section 265.92(d) specifies that groundwater contamination sampling and analysis must be conducted at least semi-annually.

If initial background concentrations must be established, Section 265.92 requires that three types of groundwater sampling and analysis be conducted: primary drinking water parameters, groundwater quality, and groundwater contamination.

Background primary drinking water parameters sampling and analysis consist of determining the concentration of each of the following parameters in the groundwater at each monitoring well: arsenic, barium, cadmium, chromium, lead, mercury, selenium, silver, pesticides (Endrin, Lindane, Methoxychlor, and Toxaphene), herbicides (2,4-D and 2,4,5-TP Silvex), radium, gross alpha, gross beta, turbidity, and coliform bacteria. Section 265.92(c) specifics that primary drinking water parameters sampling and analysis must be conducted quarterly for one year.

Background groundwater quality and background groundwater contamination sampling and analysis consist of determining the concentration for each of the parameters previously mentioned. Section 265.92(c) specifies that background groundwater quality and background groundwater contamination must be conducted quarterly for one year.

The Part 264 Subpart F regulations do not specify a minimum number of groundwater monitoring wells. Section 264.91 specifies that at least one of the following three types of groundwater monitoring programs must be instituted during closure and the post-closure care period: detection monitoring, compliance monitoring, or corrective action. Closure and post-closure groundwater monitoring costs were developed for detection monitoring and compliance monitoring only. Unless otherwise indicated in the closure or post-closure plan, it can be assumed that during closure and the post-closure care period a facility owner/operator would continue the monitoring program which was instituted during the operating life, either detection monitoring or compliance monitoring. However, if a compliance monitoring compliance period ends before the end of the post-closure care period, detection monitoring would be reinstated for the remainder of the post-closure period.

Detection monitoring is conducted to determine whether a regulated facility is leaking. The parameters or constituents to be monitored are site-specific and are specified in the Part B permit. These parameters or constituents may include indicator parameters such as pH, specific conductance, total organic carbon, and total organic halogen; specific waste constituents; or reaction products that provide a reliable indication of the presence of hazardous constituents in the groundwater. Section 264.97(g) specifies that the upgradient well(s) must be sampled quarterly for one year for the monitoring parameters or constituents to establish background groundwater quality. Costs are included in this document in case a change in background groundwater quality is suspected during closure or the post-closure care period and it becomes necessary to monitor or re-establish background groundwater quality at the upgradient well(s); or to establish initial background concentrations in the case of tank facilities closed as landfills. Section 264.98(d) specifies that detection monitoring must be conducted at least semi-annually at the compliance point (downgradient wells) for the monitoring parameters or constituents to determine the groundwater quality.

Compliance monitoring is conducted when it has been determined that hazardous constituents are leaking from a regulated facility into the groundwater.

The hazardous constituents to be monitored are site-specific and are specified in the Part B permit. A list of hazardous constituents is identified in Appendix VIII of Part 261. Section 264.97(g) specifies that the upgradient well(s) must be sampled quarterly for one year for the monitoring parameters or constituents to establish background groundwater quality. Costs are included in this document in case a change in background groundwater quality is suspected during closure or the post-closure care period and it becomes necessary to monitor or re-establish background groundwater quality at the upgradient well(s); or to establish initial background concentrations in the case of tank facilities closed as landfills. Section 264.99(c) states that in establishing concentration limits the upgradient well(s) may be sampled each time that the downgradient wells are sampled, which is quarterly. Section 264.99(d) specifies that compliance monitoring must be conducted at least quarterly at the compliance point (downgradient wells) for the site-specific hazardous constituents identified in the Part B permit. Section 264.99(f) specifies that all downgradient wells must be sampled and analyzed annually for all of the hazardous constituents listed in Appendix VIII of Part 261.

2.1.2 Groundwater Quality Analysis

During the closure period, sample collection, preparation, and delivery would be conducted by a contract lab technician. A typical time for sample collection and preparation is four hours per well. The unit labor cost for a contract lab technician is presented in the chapter of this volume entitled "Labor Categories and Rates." Groundwater quality samples would be analyzed at a contract lab. Contract lab fees are presented in Table 2-1, which shows a range of unit costs for each parameter to be analyzed and the typical cost to analyze for all six parameters.

During the post-closure period, sample collection, preparation, and delivery would be conducted by a contract lab technician. Refer to the "Labor Categories and Rates" chapter of this document for a contract lab technician unit labor cost. Groundwater quality samples collected during post-closure would be ana-

TABLE 2-1. CONTRACT LAB FEES FOR GROUNDWATER QUALITY ANALYSIS

Groundwater Quality Parameters	Unit Costs ($/analysis)	Average ($/analysis)
• chlorides	7.50 - 13.00	10.25
• iron	10.50 - 14.00	12.25
• manganese	10.50 - 14.00	12.25
• phenols	14.00 - 39.00	26.50
• sodium	10.50 - 14.00	12.25
• sulfate	8.00 - 16.00	12.00
Typical average groundwater quality analysis unit cost		$85/analysis for all parameters

lyzed at a contract lab. Refer to Table 2-1 for contract lab fees for groundwater quality analysis.

2.1.3 Groundwater Contamination Analysis

During the closure period, sample collection, preparation, and delivery would be conducted by a contract lab technician. A typical time for sample collection and preparation is four hours per well. Refer to the "Labor Categories and Rates" chapter of this document for a contract lab technician unit labor cost. Groundwater contamination samples collected during closure would be analyzed at a contract lab. Contract lab fees for groundwater contamination analysis are presented in Table 2-2. Table 2-2 shows a range of unit costs for each parameter to be analyzed and a typical cost to analyze for all four parameters.

During the post-closure period, sample collection, preparation, and delivery would be conducted by a contract lab technician. Refer to the "Labor Categories and Rates" chapter of this document for a contract lab technician unit labor cost. Groundwater contamination samples collected during post-closure would be analyzed at a contract lab. Refer to Table 2-2 for contract lab fees for groundwater contamination analysis.

2.1.4 Primary Drinking Water Parameters Analysis

During the closure period, sample collection, preparation, and delivery would be conducted by a contract lab technician. A typical time for sample collection and preparation is four hours per well. Refer to the "Labor Categories and Rates" chapter of this document for a contract lab technician unit labor cost. Primary drinking water parameters samples collected during closure would be analyzed at a contract lab. Contract lab fees for primary drinking water parameters analysis are presented in Table 2-3. Table 2-3 shows a range of unit costs for each parameter to be analyzed and a typical cost to analyze for all parameters.

TABLE 2-2. CONTRACT LAB FEES FOR GROUNDWATER CONTAMINATION ANALYSIS

Groundwater Contamination Parameters	Unit Costs ($/analysis)	Average ($/analysis)
• pH	4.00 - 5.50	4.75
• specific conductance	6.50 - 9.00	7.75
• total organic carbon	26.50 - 45.00	35.75
• total organic halogen	55.00 - 90.00	72.50
Typical average groundwater contamination analysis unit cost		$120/analysis for all parameters

TABLE 2-3. CONTRACT LAB FEES FOR PRIMARY DRINKING WATER PARAMETERS

Primary Drinking Water Parameters	Unit Cost ($/analysis)	Average ($/analysis)
• arsenic	17 - 35	26.00
• barium	16	16.00
• cadmium	9 - 14	11.50
• chromium	9 - 14	11.50
• lead	9 - 14	11.50
• mercury	25 - 34	29.50
• selenium	21	21.00
• silver	12	12.00
• pesticides (Endrin, Lindane, Methoxychlor, and Toxaphene)	100 - 125	112.50
• herbicides (2,4-D and 2,4,5-TP Silvex)	125	125.00
• radium (226 and 228), gross alpha, and gross beta	92 - 215	153.50
• turbidity	7 - 12	9.50
• coliform bacteria	11 - 85	48.00
Typical (average) primary drinking water parameters analysis unit cost		$585/analysis for all parameters

During the post-closure period, sample collection, preparation, and delivery would be conducted by a contract lab technician. Refer to the "Labor Categories and Rates" chapter of this document for a contract lab technician unit labor cost. Primary drinking water parameters samples collected during post-closure would be analyzed at a contract lab. Refer to Table 2-3 for contract lab fees for primary drinking water parameters analysis.

2.1.5 Detection Monitoring or Compliance Monitoring

Land disposal facilities regulated by the Part 264 regulations are required to conduct either detection monitoring or compliance monitoring, whichever is appropriate for the facility. Both detection monitoring and compliance monitoring may be performed at the same site.

During the closure period, sample collection, preparation, and delivery would be conducted by a contract lab technician. A typical time for sample collection and preparation for either detection monitoring or compliance monitoring is four hours per well. Refer to the "Labor Categories and Rates" chapter of this document for a contract lab technician unit labor cost. During the closure period detection monitoring or compliance monitoring samples would be analyzed at a contract lab. Because the hazardous constituents to be monitored are site-specific, costs are given for several groups of constituents that may be included under detection monitoring or compliance monitoring programs. The user of this document should select the appropriate groups of constituents from Table 2-4 for the closure plan being reviewed. Contract lab fees for detection monitoring and compliance monitoring analyses are presented in Table 2-4. All cost estimates for detection and compliance monitoring should include the following analyses because EPA expects to find the constituents at all facilities:

- Inductively coupled plasma (metals);
- AA (mercury, cold vapor);
- GC (PCBs and pesticides);

TABLE 2-4. CONTRACT LAB FEES FOR GROUNDWATER DETECTION OR COMPLIANCE MONITORING

Method and Constituents		Minimum Cost ($)	Maximum Cost ($)
6010	Inductively Coupled Plasma (Metals)	76	152
4470	AA (Mercury, Cold Vapor)	15	37
7551	AA (Osmium, Graphite Furnace)	15	50
8080	GC (PCBs and Pesticides)	90	200
8140	GC (Organophosphorous Pesticides)	125	235
8150	GC (Chlorinated Herbicides)	120	200
8240	GC (Phthalate Esters)	175	300
8270	GC (Polynuclear Aromatics)	150	200
8340	GC/MS (Volatile Organics)	240	500
8320	GC/MS (Semivolatile Organics, Capillary)	650	1,560
8330	HPLC	200	1,200
9010	Cyanides, Total and Amenable	30	110
9030	Sulfides	12	20
	Direct Injection (Water Soluble Volatiles)	100	200
	Remaining 30-40 Appendix VIII Constituents	2,000	3,000
	Total	$ 4,000	$ 8,000

- GC/MS (volatile organics); and
- GC/MS (semi-volatile organics, capillary).

Any additional analyses that have been specified in the facility permit must also be included.

The compliance monitoring program also specifies that all downgradient wells must be sampled and analyzed annually for all of the Part 261 Appendix VIII hazardous constituents. Contract lab fees for analyzing the Appendix VIII hazardous constituents are also shown in Table 2-4. It should be noted that not all of the 375 Appendix VIII hazardous constituents can be analyzed. Table 2-4 does not include costs for analyzing the 21 Appendix VIII constituents that are unstable in water or for which no EPA analytical method exists.

During the post-closure period, sample collection, preparation, and delivery would be conducted by a contract lab technician. Refer to the "Labor Categories and Rates" chapter of this document for a contract lab technician unit labor cost. Groundwater detection monitoring or compliance monitoring samples would be analyzed at a contract lab during the post-closure period. Refer to Table 2-4 for contract lab fees for detection monitoring and compliance monitoring.

2.2 SOIL MONITORING

Sections 264.280 and 265.280 of 40 CFR require that all land treatment facility owner/operators continue soil core monitoring throughout the closure and post-closure care periods. In addition, they must continue soil-pore liquid monitoring during the closure period for 90 days after the last application of waste to the treatment zone. The regulations do not specify the number of samples to be collected or the frequency of sampling for either soil core or soil-pore liquid monitoring. This section presents the unit costs and the assumptions used in developing the closure and post-closure costs for soil monitoring.

2.2.1 Soil Core Monitoring

During the closure period soil core sample collection and delivery would be conducted by a contract lab technician. A typical time for sample collection is one hour per sample.[2] This includes collecting the sample, moving between sampling locations, and completing paperwork. Unit labor costs for a contract lab technician are presented in the chapter of this volume entitled "Labor Categories and Rates." The soil core samples would be analyzed at a contract lab. The parameters to be monitored will vary among facilities, depending on the principal hazardous constituents contained in the waste being land treated. Because the parameters to be monitored are site-specific, costs are given for several parameters which may be included in the soil core monitoring program at a facility. The user of this document should select the appropriate parameters for the facility closure plan being reviewed from Table 2-5. Table 2-5 shows a cost range per sample to extract liquid from soil for analysis and a cost range per parameter for the analyses. To obtain a representative unit cost per sample for use on the soil monitoring worksheet, the user should sum the unit cost per parameter from Table 2-5 for each appropriate parameter to be analyzed for a facility. This unit cost sum equals the cost per sample for analysis. The unit cost per sample for extraction of liquid from soil should be added to the unit cost per sample for analysis to give a contract lab fee unit cost per sample for use on the worksheet.

During the post-closure care period sample collection and sample delivery would be conducted by a contract lab technician. Refer to the "Labor Categories and Rates" chapter of this volume for contract lab technician unit labor costs. During the post-closure period soil core samples would be analyzed at a contract lab. Refer to Table 2-5 for contract lab fees for soil core analysis.

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[2] PEDCo Environmental Inc., Data For Reviewing Closure and Post-Closure Costs of Hazardous Waste Management Facilities, Cincinnati, Ohio, August 1983.

TABLE 2-5. CONTRACT LAB FEES FOR SOIL ANALYSIS

Sample Preparation	Unit Cost ($/sample)
• Extract liquid from soil for analysis for any number of the following parameters/sample	12.00 - 35.00

Soil Analysis Parameters	Unit Cost ($/parameter)
• cadmium	9.00 - 30.00
• arsenic	17.00 - 40.00
• lead	9.00 - 30.00
• mercury	25.00 - 40.00
• chromium	9.00 - 30.00
• zinc	9.00 - 30.00
• copper	9.00 - 30.00
• selenium	21.00
• barium	16.00
• cyanide	39.00
• sulfide	75.00
• pH	4.00 - 5.50
• total nitrogen	20.00 - 30.00
• total solids	8.00 - 15.00
• organic matter	8.00 - 20.00
• pesticides (to identify the following four pesticides from one sample: Endrin, Lindane, Methoxychlor, and Toxaphene)	100.00 - 125.00
• herbicides (to identify the following two herbicides from one sample: 2,4-D and 2,4,5-TP Silvex)	125.00

2.2.2 Soil-Pore Liquid Monitoring

Soil-pore liquid monitoring is conducted during the closure period for 90 days after the last application of waste to the treatment zone. It is not conducted during post-closure. During this period sample collection and sample delivery would be conducted by a contract lab technician. A typical time for collecting soil moisture samples from lysimeters is one hour per sample.[3] This includes collecting the sample, moving between sampling locations, and completing paperwork. Refer to the "Labor Categories and Rates" chapter of this volume for contract lab technician unit labor costs. During the closure period soil-pore liquid samples would be analyzed at a contract lab. The parameters to be monitored will vary among facilities, depending on the principal hazardous constituents contained in the waste being land treated. Because the parameters to be monitored are site-specific, costs are given for several parameters which may be included in the soil-pore liquid monitoring program at a facility. The user of this document should select the appropriate parameters for the facility closure plan being reviewed from Table 2-6. Table 2-6 shows a cost range per parameter for analysis. To obtain a representative unit cost per sample for use on the soil monitoring worksheet, the user should sum the unit cost per parameter from Table 2-6 for each appropriate parameter to be analyzed for a facility. This sum equals a contract lab fee unit cost per sample for use on the worksheet.

Labor costs for personnel for administrative reporting and monitoring equipment maintenance during the closure period are presented in the chapter of this volume entitled "Labor Categories and Rates."

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[3] PEDCo Environmental Inc., Data For Reviewing Closure and Post-Closure Costs of Hazardous Waste Management Facilities, Cincinnati, Ohio, August 1983.

TABLE 2-6. CONTRACT LAB FEES FOR SOIL-PORE LIQUID ANALYSIS

Soil-Pore Liquid Analysis Parameters	Unit Cost ($/parameter)
• pH	4.00 - 5.50
• specific conductance	6.50 - 9.00
• total organic carbon	26.50 - 45.00
• total organic halogen	55.00 - 90.00
• arsenic	17.00 - 40.00
• barium	16.00
• cadmium	9.00 - 30.00
• chromium	9.00 - 30.00
• lead	9.00 - 30.00
• mercury	25.00 - 40.00
• selenium	21.00
• silver	12.00
• pesticides (to identify the following four pesticides from one sample: Endrin, Lindane, Methoxychlor, and Toxaphene)	100.00 - 125.00
• herbicides (to identify the following two herbicides from one sample: 2,4-D and 2,4,5-TP Silvex)	125.00

2.3 TESTING FOR SOIL CONTAMINATION

The Part 264 and Part 265 regulations require that soils contaminated with hazardous waste or hazardous waste residues must be removed at closure. In order to determine if the soil is contaminated and the areal extent of contamination, it is necessary to collect soil core samples at varying depths, analyze the soil samples, and prepare an isogram plan of the areal extent of soil contamination. This section presents the unit costs of testing for soil contamination.

2.3.1 Background Samples and Samples with Potential Contamination

Soil core sample collection and delivery would be conducted by a contract lab technician. A typical time for sample collection is one hour per sample.[4] This includes collecting the sample and moving between sampling locations. Unit labor costs for a contract lab technician are presented in the chapter of this volume entitled "Labor Categories and Rates." The soil core samples would be analyzed at a contract lab. The parameters to be analyzed to determine whether the soil is contaminated will vary depending on the chemical properties of the wastes that the facility receives. Because the parameters to be tested are site-specific, costs are given for a variety of parameters. The user of this document should select the appropriate parameters for contaminated soil testing from Table 2-5. The user should also refer to the contract lab fee discussion in "Soil Core Monitoring" to obtain unit costs and time requirements for use on the worksheet.

2.3.2 Preparation of Isogram Plan

An isogram plan would be prepared by a contract engineering firm. Unit labor costs for contract personnel to prepare an isogram plan are presented in

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[4] PEDCo Environmental Inc., Data For Reviewing Closure and Post-Closure Costs of Hazardous Waste Management Facilities, Cincinnati, Ohio, August 1983.

the chapter of this volume entitled "Labor Categories and Rates."

2.4 GAS MONITORING

Sections 264.310 and 265.310 of 40 CFR require, as a part of landfill closure and post-closure, the monitoring and maintenance of the gas collection and control system, if there is one present in the landfill. This section presents the unit costs and the assumptions used in developing the costs for gas monitoring.

During closure and the post-closure care period gas monitoring would be conducted by a contract lab technician. A typical time for monitoring a well is 0.25 hour per well. This includes time for calibration of monitoring equipment, setting up a portable VOC monitor at the well, reading and recording the results, and moving to the next sampling location. Unit labor costs for a contract lab technician are presented in the chapter of this volume entitled "Labor Categories and Rates."

Gas monitoring well inspection and well maintenance during the post-closure care period are discussed in the chapter of this volume entitled "Inspection and Maintenance."

2.5 AIR QUALITY MONITORING

Sections 264.347 and 265.347 of 40 CFR require that all incinerator facilities conduct air monitoring when incinerating hazardous wastes. This section presents information regarding air quality monitoring costs.

To comply with the regulatory requirement that cost estimates be based on third-party costs, it was assumed that if inventory is incinerated on-site the work would be performed by contract personnel. Air monitoring must be conducted

throughout the entire burn time. Minimum monitoring requirements consist of monitoring the combustion temperature, waste feed rate, the indicator of combustion gas velocity, and carbon monoxide on a continuous basis. It was assumed that instrumentation related to combustion and emission control is automatically controlled and that the instruments are connected to an alarm system which would sound if steady-state conditions are not maintained. It was also assumed that the process operator who is present during inventory incineration (see Worksheet C-1 - Inventory Management) would monitor the instruments and would contact appropriate personnel if the alarm sounded. Consequently, there are no additional process operator labor costs for air quality monitoring.

The emergency waste feed cut-off system and associated alarms must be tested at least weekly to verify operability, unless the applicant demonstrates to the Regional Administrator that less frequent inspection will be adequate. At a minimum, operational testing must be conducted at least monthly.

Air quality monitoring data must be recorded and the records must be placed in the operating log. It was assumed that air quality monitoring costs would consist of the time required for a technician to test the waste feed cut-off system, change the graph paper in the monitoring instruments daily, place the graphs and any necessary descriptive information in the operating log, and if necessary, select points from the graphs and record the data in the operating log. Labor costs for facility personnel for administrative reporting are estimated and documented in the "Labor Categories and Rates" chapter of this volume.

Upon request by the Regional Administrator, sampling and analysis of the waste and exhaust emissions must be conducted to verify that the operating requirements established in the permit achieve the performance standards of Section 264.343 of 40 CFR. Costs for this type of sampling and analysis depend on the scope of the testing required by the Regional Administrator. Examples of sampling and analysis plans that may be required by the Regional Administrator are given below along with estimated cost ranges. Costs for establishment of a Volatile Organic Sampling Train (VOST) and subsequent constituent analysis may

range from $50,000 to $75,000. Costs for a Modified Method V sampling and analysis for volatiles and semi-volitiles may range from $20,000 to $50,000.

CHAPTER 3

INSPECTION AND MAINTENANCE

Inspection and maintenance activities are included in both closure and post-closure of a facility. In general, the unit cost for inspections will be for a field technician; maintenance unit costs will usually consist of a materials cost and a labor cost for performing repairs and/or installation. During both closure and post-closure all inspection and maintenance activities will be conducted by contracted labor. Closure inspection and maintenance includes:

- routine inspection and repairs at the facility;
- repair of drainage channels at land treatment facilities; and
- inspection and maintenance of all monitoring, detection, and collection systems.

Post-closure inspection and maintenance activities include:

- routine facility inspections and repairs;
- repair of vegetative covers due to severe erosion damage;
- maintenance of surveyed waste management area boundary markers; and
- inspection and maintenance of all monitoring, detection, and collection systems.

The next section discusses inspection and maintenance activities that could be part of both closure and post-closure (except repairing land treatment drainage channels and maintaining lysimeters, which would be done during closure). The section following it deals with activities that are performed during post-closure only.

3.1 CLOSURE AND POST-CLOSURE INSPECTION AND MAINTENANCE

Routine maintenance and repairs during closure and post-closure consist of various activities. Many of these activities are labor-intensive and the costs

are based on the number of hours required to do them. Detailed information on labor rates can be found in the chapter of this volume entitled "Labor Categories and Rates".

Overall facility inspection involves a technician, who does the actual inspection, and an engineer, who supervises the technician. Administrative services include the engineer and technician, who prepare inspection reports, and a clerical person, who types and files the reports. Unit labor costs for these personnel are found in the "Labor Categories and Rates" chapter of this volume.

Some closure and post-closure inspection and maintenance activities primarily involve a technician to perform inspections and a laborer to perform the necessary repairs. This is true of inspections and maintenance for the following:

- leachate collection systems;
- leak detection systems;
- gas monitoring wells; and
- groundwater monitoring wells.

All of the inspection and maintenance work would be performed by contracted labor.

3.1.1 Repair of Drainage Channels

At the time of closure, drainage channels at a land treatment facility may need to be cleaned and repaired. Cleaning the channel involves removing deposits of silt and organic matter down to the original channel boundary. Sections of the channel that have eroded must be regraded to the original contour then revegetated to prevent further erosion. The unit cost for hand grading is $2.46 per square yard. Unit costs for revegetating the parts of the drainage channels that have been repaired are the same as routine erosion damage repair costs --$1334 per acre for seeding, $290 per acre for fertilizing, and $2904 per acre for mulching.

3.1.2 Leachate Collection System Maintenance

Leachate collection system maintenance may involve replacing the pump and cleaning out the leachate collection system branches periodically. Table 3-1 lists various sized sump pumps and their unit costs (including installation). These pumps are automatic and have a 10-foot head. If the leachate is not very corrosive and has a low concentration of particulate matter, the pump could be expected to last 10 years. A leachate that is corrosive and/or high in particulates could reduce the pump life to two to five years. The need for pump maintenance and replacement during the operating life of the facility should provide a good guide for maintenance and replacement frequencies during closure and post-closure.

Leachate collection system branches should not need to be replaced. Sanitary sewers are designed for a 50 year life span. Leachate collection systems should have a similar life span. The leachate collection system branches may become clogged with fines and need to be cleaned out. Leachate collection system branches are cleaned by backwashing with a low volume of water under high pressure. The unit cost for cleaning out the branches is $35.35/hr. This cost includes equipment rental and labor. The branches would not need frequent cleaning during the post-closure care period because the volume of leachate generated would be decreasing once the final cover is applied.

3.1.3 Groundwater Monitoring Well Construction or Replacement

Groundwater monitoring wells or well parts may need replacement. Groundwater monitoring wells should last 25 years or more if the groundwater is not very corrosive. This is based on the assumption that the well is constructed of materials that are appropriate for the contaminants expected (e.g., stainless steel well screening if any groundwater contamination is expected to contain organics).

If the casing needs replacement it is more economical to seal the well needing casing replacement and construct a new well. The unit cost for sealing the existing well is $3/ft. A typical cost for sealing a 100-ft well would be

TABLE 3-1. SUMP PUMP UNIT COSTS (Bronze)*

Pump Size (gpm)	Cost ($/pump)
22	265
68	400
94	535
105	525

* Unit costs include labor costs for installation.

$300. The unit cost for constructing a new well is $2,425/well. This includes materials (stainless steel casing, screen, pump, tubing, and cap and lock) and installation. The well itself is two inches in diameter and is 50 feet deep. For additional length, $34 per vertical lineal foot must be added to the unit cost given above. A typical cost for a 100-ft well would be $4,125 plus $150 for mobilization/demobilization.

Groundwater monitoring well parts that may need replacing include pumps, tubing, and caps. The typical costs for a teflon bladder pump is $495 and for teflon lined tubing is $2.75/ft. A typical well cap cost is $70 per cap.

If a tank facility is closed as a landfill, the owner or operator must perform closure and post-closure care as a landfill. This includes implementation of a groundwater monitoring program. Because tank facilities are not required to have a groundwater monitoring system, it would be necessary to construct groundwater monitoring wells during the closure period. A typical mobilization/demobilization cost for constructing a new well is $150. A typical unit cost for drilling and installation is $22 per vertical lineal foot. The unit cost for two inch diameter stainless steel casing including fittings is $9/foot. Depending on the type of soil, a well screen ranging in length from five to ten feet may be required. The unit cost for a two inch diameter 10 foot well screen is $290/each. The typical cost for a teflon bladder pump is $495/each. The unit cost for teflon lined tubing for withdrawing the groundwater sample is $2.75/ foot. A typical well cap cost is $70/cap.

3.1.4 Lysimeter Maintenance

As discussed in the "Monitoring and Testing" chapter, soil-pore liquid must be monitored at land treatment facilities for 90 days after the last application of waste to the treatment zone. The lysimeters used for this monitoring may need replacement at the time of closure. The cost for replacing a lysimeter is $132, which includes both materials and labor to prepare and replace the lysimeter. In addition, total costs for travel to and from the site are estimated to be $85 per hour.

3.1.5. Security System Maintenance and Repair

Maintenance and repair of the security system during closure and post-closure involve labor, materials, overhead, and profit. Items at the facility that may need to be maintained or repaired include fencing, gates, posts, and other security items such as barbed wire and signs. Depending on the layout of the facility, fencing may have to be installed for the first time. The cost for fencing is for industrial chain link fencing, six feet high with three strands of barbed wire at the top. Included in this unit cost are two-inch line posts positioned 10 feet off-center, with one and five-eighths inch top rail. The cost for six-gauge galvanized steel fencing is $10.55 per lineal foot; without the barbed wire the cost is $10.10 per lineal foot. These costs would be approximately 20 percent higher if aluminized steel, rather than galvanized steel, is used. All costs for security system items also include the labor required to install them. The unit cost for a gate three feet wide and six feet high with a three-inch frame made from galvanized steel is $80 per gate. Additional corner posts for the fence, three inches in diameter, cost $57 per post. Barbed wire unit costs range from $28 per 1000 lineal feet to $110 per 1000 lineal feet; the most typical unit cost is for 15-1/2 gauge imported steel at $28 per 1000 lineal feet. For stainless steel helical fence topping the unit cost is $110 per 100 lineal feet. Fencing, gates, barbed wire, and helical fence topping should all last about 30 years, barring accidental damage or vandalism. However, galvanized materials will have a shorter life than this if exposed to salty sea spray or chemical fumes (e.g., refinery emissions). In such situations aluminized materials are recommended. The user should rely on facility operating experience for security system life if adverse conditions are likely.

Signs around a facility may also need replacing during closure or the post-closure period. A standard reflectorized sign is estimated to last about seven to eight years. As with fencing, sign life may be less than this if the sign is exposed to salty sea spray. The user should rely on facility operating experience for sign life if sea spray exposure is likely. For a reflectorized directional sign, approximately 12 inches by 18 inches, the unit cost is $21 per sign. If a post also needs replacing, the unit cost for a 10-foot steel post is

$29 per post, or $34 per post if a 12-foot post is needed. Signposts should have a life of 30 years unless exposed to a corrosive atmosphere. Typical unit costs for security system maintenance and repair are presented in Table 3-2.

3.1.6 Wind Dispersal Structure Inspection and Repair

If the land treatment zone contains particulate matter which may be subject to wind dispersal, the owner or operator must manage the unit to control wind dispersal. The owner or operator must inspect the unit weekly and after storms to detect evidence of improper functioning of wind dispersal control measures. Types of wind dispersal methods may range from rows of conifers such as blue spruce in regions with temperate climates to a polypropylene fence or screen in regions with an arid climate. A typical unit cost for blue spruce replacement is $140/tree. This includes the tree and labor. A typical unit cost for a polypropylene fence or screen replacement is $2.76/ft. As wind dispersal control measures must be in place over the active life of the facility, operators can use past experience as a guide to replacement frequency.

3.1.7 Surveying and Maintenance of Waste Management Area Boundaries

One of the last closure activities performed is surveying the boundaries of the waste management area(s) with respect to permanently surveyed benchmarks and installing posts to mark these boundaries. The surveying would be performed by a professional land surveyor, who would be assisted by a surveyor's assistant or technician. A fence post would be installed to mark the boundary corners. Unit labor costs are presented in the "Labor Categories and Rates" chapter of this volume. Replacement of the fence posts during the post-closure period would incur a cost of $29 per post for materials and labor. As with security system items, fence post life should be about 30 years unless adverse conditions are expected. Replacement frequency during post-closure should be the same as for the fence, gates, etc.

TABLE 3-2. UNIT COSTS - SECURITY SYSTEM*

Item	Unit Cost Range	Typical Unit Cost
Fence (with barbed wire)	$7.55 - $11.95/L.F.	$10.55/L.F.
Fence (no barbed wire)	$10.10 - $11.55/L.F.	$10.10/L.F.
Barbed wire	$28.00 - $110.00/1000 L.F.	$28.00/1000 L.F.
Helical fence topping	$99.00 - $121.00/100 L.F.	$110.00/100 L.F.
Gate	$80.00 - $93.00/gate	$80.00/gate
Corner posts	$57.00 - $67.00/post	$57.00/post
Sign	$21.00 - $48.00/sign	$21.00/sign
Signpost (10 ft)	---	$29.00/post
Signpost (12 ft)	---	$34.00/post

* Unit costs include labor costs for installation.

3.2 POST-CLOSURE INSPECTION AND MAINTENANCE

3.2.1 Mowing and Sprinkling

The frequency of grass mowing and sprinkling during post-closure will vary by region of the country, depending on the climate and precipitation. In order to estimate these frequencies, two issues the user should keep in mind are: the rate at which grass grows in the area in which the facility is located and the number of months in the growing season. Upper and lower bounds that may be useful for determining cover mowing frequency are residential lawn mowing frequency and highway maintenance (if applicable) mowing frequency, respectively. Mowing would be done using a tractor mower. A typical unit cost would be $25 per acre for an outside firm to do the mowing. This cost includes both equipment and labor.

The same types of issues apply when determining a sprinkling frequency. Sprinkling rate, however, would probably be substantially lower for vegetative cover areas than for a residential lawn because the main objective would be to keep the vegetation living. Sprinkling involves driving a water tank truck to the site and watering the vegetative cover. The daily cost, including labor and equipment, for a 5000 gallon truck is $420. The cost for one-half day equipment rental and labor would be $210. Assuming multiple trips to the site, it is estimated that the maximum daily amount of water that could be sprinkled would be 20,000 gallons, based on a one-way distance to the site of 10 to 15 miles. The user will need to consider both the quantity of water needed for sprinkling and the distance to the site in estimating the number of days needed.

3.2.2 Fertilizing

The unit cost for fertilizing is the same as that presented in the "Final Cover and Revegetation" chapter of this volume--$176 per acre, with an equipment mobilization/demobilization cost of $105. Unless otherwise noted in the post-closure plan, the user should assume that the entire vegetative cover will be fertilized once per year.

3.2.3 Re-establishment of Vegetative Cover and Other Cover Repairs

This includes re-establishment of the vegetative final cover and repair of routine erosion damage to the final cover, diversion ditches, dikes, and berms. The activities are generally the same as those presented in the "Final Cover and Revegetation" chapter -- seeding, fertilizing, and mulching. However, a push spreader is used instead of a tractor or hydraulic spreader, because it is expected that a smaller area will need repair. Table 3-3 presents unit cost ranges and typical unit costs for seeding, fertilizing, and mulching using a push spreader. Incorporated into each cost are the application rates and the labor involved with each activity. For all routine repairs of erosion damage, the seed used is slope mix with an application rate of 261 pounds per acre; fertilizer is applied at a rate of 968 pounds per acre; and peat moss is spread one inch deep for mulch. For re-establishing final cover in areas where the seed germinated poorly, the application rate for seed should be approximately one-half of the initial seed application rate (131 pounds per acre). Fertilizing would probably not be necessary if re-seeding is done during the same growing season as initial seeding. If re-seeding is to be done in the subsequent growing season, fertilizer as well as seed should be applied. The percent of the final cover area that will need re-seeding is highly variable. Discussions with coal companies about their experience with revegetation of strip mined areas have indicated that with good-quality topsoil and adequate post-seeding care, no re-seeding should be necessary. In addition, experience at the facility during its operating life (e.g., establishing vegetation on berms) or with earlier partial closures may be used as a guide for determining how much final cover re-seeding will be necessary.

In arid regions of the country crushed stone may be used instead of vegetation for controlling erosion. Similar to vegetation, the crushed stone layer may need to be repaired periodically due to routine erosion damage. The activities are generally the same as those presented in the "Final Cover and Revegetation" chapter -- crushed stone, except the crushed stone would be placed by hand and compacted using a walk behind roller because a smaller area will need repair. Table 3-4 presents unit cost ranges and typical unit costs for crushed stone purchase, delivery, spreading, and compaction.

TABLE 3-3. UNIT COSTS - POST-CLOSURE VEGETATIVE COVER REPAIR

Activity	Unit Cost Range ($/acre)	Typical Unit Cost ($/acre)
Seeding for routine erosion damage repair	1079 - 2700	1334
Re-seeding of final cover	1027 - 1838	1155
Fertilizing	290 - 9728	290
Mulching	2662 - 3146	2904

TABLE 3-4. UNIT COSTS - POST-CLOSURE CRUSHED STONE COVER REPAIR

Activity	Unit Cost Range ($/yd^3)	Typical Unit Cost ($/yd^3)
Purchase crushed stone	-	11.55
Delivery	1.56 - 10.16	2.61
Spreading	-	15.35
Compaction	1.38 - 5.20	4.14

Both diversion ditch repair and routine erosion damage repair must include the cost of off-site borrow if on-site borrow is not available. Enough borrow is needed to fill eroded areas of diversion ditches to the original contour. The unit cost of borrow, $17.60 per cubic yard, includes purchase, delivery (five-mile one-way haul distance), and the cost for a laborer to grade the soil by hand.

3.2.4 Repair of Severe Erosion or Frost Damage

The activities undertaken to repair severe erosion or frost damage to a vegetative cover would be those to place, spread, and compact topsoil and revegetate the repaired area. The unit costs are the same as those presented for native soil, purchased topsoil, revegetation, and mobilization/demobilization in the "Final Cover and Revegetation" chapter of this volume. The frequency with which this type of repair would need to be done should be based on such things as the number of severe rainstorms that occur annually in the area where the facility is located and the amount of erosion expected during the spring snowmelt (if applicable).

3.2.5 Rodent Control

Rodent control has a typical unit cost of $30 per acre for extermination materials; labor is provided by a contract laborer. The activity may occur with varying frequency depending on the geographical location of the facility and whether burrowing rodents are expected to be a problem.

3.2.6 Maintenance of pH at Land Treatment Facilities

During the post-closure period at land treatment facilities, lime may be needed to maintain the soil pH between 6 and 7 so that plants and microbes can flourish in the soil. The addition of large quantities of organic wastes during land treatment causes organic and inorganic acids to be formed and released as the organic wastes decompose. The native soil may then become too acidic for the waste decomposition process to continue or for the vegetative cover to grow

well. The cost for maintaining the pH in the desirable range depends on the amount of rainfall in an area, the type of topsoil, and the quantity of fertilizer that has been added.

A typical application rate for vegetative cover is 2.5 tons of ground limestone per acre for the initial application plus 0.5 tons per acre every three to six years thereafter. Over 30 years this would be one initial application plus five to ten supplementary applications. In cases where petroleum wastes have been applied and decomposition of the organics is complete, frequent lime additions may be necessary to limit metals migration from the treatment zone, particularly where the soil has insufficient cation exchange capacity to keep the toxic metals immobilized. The typical cost for the initial application is $214 per acre, and the cost for supplementary applications is $60 per acre. mobilization/demobilization of the equipment is $105 per visit.

CHAPTER 4

INVENTORY AND RESIDUAL MANAGEMENT

For facilities that are not engaged in disposal activities, the removal, treatment, and disposal of inventory and waste residues will frequently be the largest single cost element. The unit costs of inventory treatment and/or disposal are dependent upon whether the materials will be managed on-site or removed to an off-site commercial hazardous waste facility. If disposal or treatment takes place on-site, the unit costs can be expected to be lower than when removing inventory to an off-site TSDF.

This chapter presents the unit costs and prices used in developing costs for transport, treatment, and disposal of waste inventory and residuals. It is divided into two sections, on-site management and off-site management, to identify different practices that facility owner/operators may select to manage their wastes. In accordance with the regulatory requirement that cost estimates be based on third-party costs, all activities are assumed to be performed using contracted personnel and equipment. Also, closure costs must include the costs of handling, treating, and/or disposing of the maximum inventory that will be on-site at any one time during the operating life of the facility.

4.1 ON-SITE MANAGEMENT OF WASTE INVENTORY AND RESIDUALS

The disposal of remaining waste inventory, treatment and decontamination residuals, leachates, and contaminated soils and other facility structures will take place on-site at many facilities. This section contains typical costs for a variety of on-site waste and residual management activities as well as costs for utilities needed for the waste management processes. Utility and material costs are listed and described in Table 4-1. Cost estimates for specific on-site waste and residual management activities using third-party labor and rental equipment are described in the following sections.

TABLE 4-1. UTILITY AND MATERIAL COSTS

Utility/Material	Unit Cost
Gasoline/Diesel Fuel	$0.94/gal
Electricity	$0.05/kWh
Incinerator Auxiliary Fuel Costs	
• No. 2 Fuel Oil	$1.04/gal ($7.62/million BTU)
• No. 6 Fuel Oil	$0.79/gal ($5.16/million BTU)
• Natural Gas	$4.15/1000 ft^3 ($4.07/million BTU)
Water	$0.91/100 ft^3 ($1.22/1000 gal)
Sewer Charge	$1.50/1000 gal
Incinerator Ash Disposal	
• Secure Landfill	$100/ton
• Sanitary Landfill	$14.00/ton
Hydrated Lime (pH control during tne removal of acid gases)	$48.00/ton
Solidification Raw Materials	
• Cement	$ 0.033/lb
• Fly Ash	$ 0.016/lb

4.1.1 Impoundment Dewatering

Three dewatering methods were considered for removing standing liquids from the impoundment.

- Solar evaporation - Solar evaporation is feasible only in specific areas and times of the year. Cost estimates will likely be based on normal annual maintenance costs (which are highly variable) and the length of time required for evaporation. The only cost guidance available is $0.045 per gallon of impoundment capacity, which is based on a 10-year average life cycle cost for an impoundment.

- Pumping out - Dewatering can be accomplished by pumping the free liquids to another impoundment not undergoing closure or by pumping into tank trucks for transport to an off-site disposal facility. Costs to rent and operate pumps with third-party labor are provided in Table 4-2.

- Discharge to POTW - Assuming that the surface impoundment is connected to a sewer and the facility is permitted for discharge, the rate is $1.50 per 1000 gallons.

4.1.2 Impoundment Sludge Removal

Sludge may or may not be removed from the impoundment following dewatering (as described above) and air drying of the sediment. If the sludge cannot be dried enough to allow heavy equipment to enter the impoundment, a dragline (positioned at the edge of the impoundment) would be used to remove the sludge. An alternative method for wet sludge removal is to use a portable floating dredge which augers the sludge and then pumps it to shore.

Table 4-3 provides cost estimates per cubic yard of sludge removed and truck loaded using off-site labor and various heavy equipment. Mobilization/demobilization costs for the appropriate heavy equipment should also be included. Once the contaminated material has been removed, costs for transport and disposal will also be incurred as discussed later in this section.

TABLE 4-2. PUMPING COSTS FOR IMPOUNDMENT DEWATERING

Pump Capacity	Cost ($/1000 gallons)
8,000 GPH	4.70
15,000 GPH	3.25

TABLE 4-3. COSTS FOR SLUDGE REMOVAL FROM IMPOUNDMENTS

Equipment Type	Equipment Size (yd^3)	Unit Cost ($/$yd^3$)	Daily Output (yd^3)	Mobilization/ Demobilization Cost ($)
Track Mounted Backhoe	1	3.90	240	165
	1-1/2	3.39*	320	210*
	2	3.32	400	255
	3-1/2	2.51	800	390
Track Mounted Front-End Loader	1-1/2	1.70	370	115
	2-1/2	1.58	510	145
	3-1/2	1.43*	690	175*
	4-1/2	1.70	850	205
Shovel	3/4	3.44	270	140
	1	3.11	320	165
	1-1/2	2.33*	480	210*
	3	1.89	800	345
Dragline	3/4	6.08	190	140
	1-1/2	3.90*	350	210*
	3	2.94	600	345
Portable Floating Dredge	-	2.09*	720	500*

* Denotes "typical" unit and mobilization/demobilization costs for each equipment type.

4.1.3 Impoundment Sludge Stabilization

If the sludge is to remain in place, stabilization is done to ensure that it is sufficiently consolidated to provide long-term support for cover materials. Before the sludge can be stabilized, however, impoundment dewatering must first be performed. Many of the solidification techniques are proprietary and highly waste-specific, resulting in a wide range of costs for stabilization. Because of the importance in selecting the proper solidification technique for the waste type and quantity, it is assumed that the facility would contract with a company providing this service. The estimated price range for waste solidification is $35 to $165 per ton of sludge, depending on the level of pretreatment required. Another study indicated the price to be approximately $100 per ton when worker health and safety costs were added to the base (non-hazardous) price of solidification. If information on the cost of solidification is not provided, an estimate of $100 per ton of sludge should be used.

4.1.4 Waste Pile Removal and Loading

The costs to remove wastes from the waste pile area and to load them onto a truck for transport and disposal are presented in Table 4-4. These costs are for off-site labor and heavy equipment. In addition, Table 4-4 contains heavy equipment mobilization/demobilization costs.

4.1.5 Containerization of Bulk Wastes

The containerization of bulk liquid wastes from an elevated tank is assumed to be accomplished by moving an empty 55-gallon drum under the tank, opening a valve, and allowing the drum to fill. When the drum is full the valve is closed and the drum is sealed and moved onto a pallet. The time needed to fill and seal each drum is estimated to be 15 minutes per drum. The cost for containerization, including third-party labor, drums, and rental of a drum lift for moving the filled drums, is estimated to be $69 per drum.

The containerization of bulk solid wastes into 55-gallon drums is assumed to be done by hand. The waste material is shoveled into a drum and the drum is

TABLE 4-4. COSTS FOR WASTE PILE REMOVAL

Equipment Type	Equipment Size (yd^3)	Unit Cost ($/$yd^3$)	Daily Output (yd^3)	Mobilization/ Demobilization Cost ($)
Track Mounted Front-End Loader	1-1/2	1.13	560	115
	2-1/2	1.05	760	145
	3-1/2	0.95*	1040	175*
	4-1/2	1.13	1280	205
Wheel Mounted Front-End Loader	3/4	1.54	360	90
	1-1/2	0.98	640	115
	3	1.02*	800	160*
	5	0.85	1450	225

* Denotes "typical" unit and mobilization/demobilization costs for each equipment type.

sealed and moved onto a pallet for transport or storage. Assuming that a laborer can fill, seal and move nine drums per day, the cost (including the 55-gallon drum) is $84.72 per drum.

4.1.6 Recontainerization of Containerized Waste

Drums that are leaking must be handled such that the leaking materials will be contained. In such situations, the entire 55-gallon drum will be enclosed in an 85-gallon salvage drum instead of emptying the contents of the leaking drum into a new drum. A drum lifter is used to hoist the drum into the air so that it can be lowered into the salvage drum. Assuming it takes 20 minutes per drum to lift and place the 55-gallon drum into the salvage drum, seal the salvage drum, and load it, the total cost (including the cost of a new salvage drum) is $144/drum.

4.1.7 Container Inventory Quantity

The quantity of inventory to be managed must include full and empty containers as well as the waste. It is assumed that empty containers will be managed in one of three ways. The empty containers may be disposed of with the full containers or they may be triple-rinsed then recycled or disposed of in a sanitary landfill. An average container weight of 55 pounds must be added to the quantity of material to be managed if the containers are to be disposed of with the waste. If the rinsed containers are to be recycled, no revenue is assumed.

4.1.8 Container Loading

The time requirement for moving and loading 55-gallon drums varies with the type of equipment and the distance from the storage area to the truck. Assuming that a pallet holds four 55-gallon drums and the number of non-palletized drums is negligible, approximately 10 pallets or 40 containers can be loaded in an hour. This includes the time to briefly inspect, record, transport, and load each pallet of drums. The cost for this activity is $4.66 per pallet, which

includes labor, equipment, and operating costs. A fully loaded trailer of 80 drums would take two hours to load, at a total cost of $93.

4.1.9 Landfill Inventory/Residual Disposal

The cost to place remaining waste inventory or residuals in an on-site landfill is based on cost of heavy equipment operated by third-party laborers. These cost estimates, presented in Tables 4-5 and 4-6, are appropriate for placing bulk solids or containerized waste in a landfill cell or trench. Mobilization/ demobilization costs for the heavy equipment are also included in the tables.

4.1.10 Absorption of Free Liquids in Containers

Free liquids must be absorbed or solidified if they are to be landfilled. This is accomplished by third-party laborers prior to on-site disposal. Assuming that each drum with free liquid has sufficient space to add absorbent material, a reasonable cost for stabilization would be $7 to $16 per drum, including labor and materials. This cost range assumes that the drum contains between one inch (about two gallons) and six inches (10 gallons) of free liquids. A typical cost of $10.50 per drum for absorbing three inches (five gallons) of free liquids is suggested.

Solidification is the only pretreatment method that is assumed to be used for containerized waste. Solidification is only necessary if the waste is to be disposed in a landfill. It is assumed that no pretreatment is needed if waste is to be incinerated or if it is to be treated at a land treatment facility.

4.1.11 Sludge Dewatering Prior to Landfill Disposal

Excavation sludges may be dewatered before on- or off-site disposal if a filter press is present on-site. Costs for industrial sludge dewatering using a belt filter press include labor, utilities, and materials. The cost is $5.50 per wet ton of sludge processed. Sludge is dried to approximately 30 percent solids content. Assuming an initial solids content of 5 percent, the final dewatered sludge quantity is one-sixth (0.17) of the original (wet) sludge amount.

TABLE 4-5. COSTS FOR ON-SITE LANDFILL DISPOSAL OF BULK SOLIDS

Equipment Type	Equipment Size	Unit Cost ($/yd^3)	Daily Output (yd^3)	Mobilization/ Demobilization Cost ($)
Dozer	75 HP	5.58	200	92
	105 HP	5.28	310	98
	200 HP	3.98*	600	117*
	300 HP	3.38	863	136

TABLE 4-6. COSTS FOR ON-SITE LANDFILL DISPOSAL OF CONTAINERIZED WASTES

Equipment Type	Equipment Size	Unit Cost ($/ton)	Daily Output (tons)	Mobilization/ Demobilization Cost ($)
Track Mounted Front-End Loader	1-1/2 yd^3	2.26	260	115
	2-1/2 yd^3	2.10*	350	145*
	3-1/2 yd^3	1.90	480	175

* Denotes "typical" unit and mobilization/demobilization costs for each equipment type.

4.1.12 Solidification of Bulk Wastes Prior to Landfill Disposal

Certain wastes containing free liquids must be solidified on-site if they are to be disposed in a landfill at the facility. In general, this can be accomplished by the addition of cement or fly ash to the waste and batch mixing in a powered concrete mixer. The cost estimates prepared for this activity are based on the use of third-party labor and equipment and include the purchase of cement or fly ash. A processing rate of 1.5 tons per hour is estimated. The resulting costs are $81 per ton for cement-based solidification and $55 per ton for wastes solidified with fly ash. Approximately a 100 percent weight increase should be expected.

4.1.13 Leachate/Run-Off Removal

The cost for the removal of leachate, run-off, or other hazardous liquids collected in on-site sumps or tanks is estimated for both closure and post-closure periods. These cost estimates are based on contracted labor rates and pump operating costs. If no pump is presently installed on-site, a pump rental fee must be added to the cost of closure pumping. For post-closure, pump rental is assumed. The pump capacity is 8000 gallons per hour.

- Closure pumping: $23.00 per hour (plus optional $2.70 per hour pump rental)
- Post-closure pumping: $25.70 per hour

4.1.14 Landspreading of Inventory/Residuals

Costs for on-site landspreading both liquid and solid waste using third-party labor and equipment were estimated. For liquids and wet sludges which can be pumped, the cost is $6.50 per ton. The mobilization/demobilization cost for a sludge applicator truck is $150. For solids which must be spread and disked into the soil, the cost is $9.25 per ton. Experience from facility operating life should be used to determine the waste application rate in tons/acre. The cost for mobilization/demobilization of a tractor with disking attachments is $125. To provide soil conditioning and pH control, ground limestone is spread with third-party equipment and labor at a cost of $214 per acre.

During the closure period at land treatment facilities, the soil must be kept aerated so that the soil microbes will remain active. As the soil settles, the microbes use their available oxygen. Without replenishment of oxygen from the surface, the soil may go anaerobic. Periodic disking is used to turn and loosen the soil to optimize conditions for biodegradation by keeping it aerated. Frequency of disking to assure adequate aeration should be based on historical operating experience, because it will be dependent on waste type, soil type, and the amount of precipitation in the region. The typical cost for renting and operating at tractor with a disk attachment is $14.40 per acre.

4.1.15 Incineration of Inventory/Residuals

The cost for incineration of inventory on-site is primarily a function of the labor, auxiliary fuel, electricity, and lime costs. Unit costs for utilities and other supplies are presented in Table 4-1, and the unit labor cost for a process operator is $25 per hour (see Table 9-1). In addition to operating the incinerator, the process operator is also responsible for inspecting the incinerator and its associated equipment daily (40 CFR §§264.347 and 265.347) and the waste feed cut-off weekly (40 CFR §264.347).

The ash generation rate is a function of the physical state of the waste and how well it burns, which can be quite variable. If no waste-specific information is provided, the user can select from the recommended ash generation rates of 0.19 tons per ton of waste for solid wastes, 0.11 tons per ton for slurry wastes, and 0.03 tons per ton for liquid wastes.

4.1.16 Treatment of Liquid Inventory/Leachates/Residuals

Costs for on-site treatment of wastes, leachates, and/or residuals are highly variable and are a function of the intrinsic waste characteristics, treatment system capacity, and residual quality. Waste type and constituent concentrations, as well as whether a waste is highly toxic, corrosive, ignitable, or reactive, will dictate a variety of handling and treatment processes.

Treatment system complexity and size are determined by waste volume, physical form (some wastes may require pretreatment steps such as filtration), and the number and type of constituents which must be treated. These factors determine system design and engineering, equipment selection, labor assignments, chemical and energy requirements, and residual management costs. Due to the variability of these factors, it is not possible to reasonably estimate on-site treatment costs. Operating cost information (e.g., labor hours and rates, chemical costs, energy use expenses, and residual management costs) should be obtained from facility records and be used to estimate the costs of on-site waste treatment during closure and post-closure periods.

4.2 OFF-SITE MANAGEMENT OF WASTE INVENTORY AND RESIDUALS

The disposal of remaining waste inventory, treatment and decontamination residuals, leachates, and contaminated soils, liners, and other facility structures may be accomplished off-site at a commercial hazardous waste facility. This section contains typical prices for transportation and to landfill, incinerate, inject, landspread, or treat the waste at commercial facilities.

4.2.1 Transportation Prices

Estimates have been prepared for the price to transport three different waste types--bulk solids, bulk liquids, and containerized wastes--over a range of one-way haul distances. Full net loads for these trucks range from 20 to 25 tons, resulting in combined weights which do not exceed the legal limit of 80,000 pounds GVW. The key assumptions used in developing these price estimates are presented in Table 4-7, for a 250-mile haul. If information on haul distances to commercial hazardous waste management facilities is not available, a typical one-way haul distance of 250 miles is suggested. A minimum one-way distance of 25 miles should be assumed. Price estimates are reported in dollars per one-way mile and are shown in Table 4-8. These estimates include the costs of waste shipment to a hazardous waste treatment or disposal facility as well as the costs for the return trip.

TABLE 4-7. TRANSPORTATION MODEL ASSUMPTIONS

	Bulk Solid Trailer (22 tons)	Tanker (6000 gal or 25 tons)	Stake Truck for Containers (20 tons)
Truck capacity used	100%	100%	100%
Loading/unloading time[1]	1 hr	2 hrs	3 hrs
Average speed	40 mph	40 mph	40 mph
Annual fixed cost[2]	$82,650	$88,650	$79,350
Variable cost[3]	$ 0.39/mi	$ 0.44/mi	$ 0.37/mi
Profit	10%	10%	10%
Amortization period	8 years	8 years	8 years
Interest rate	10%	10%	10%
Truck utilization rate	80%	80%	80%
Labor rate (incl. fringe)	$16.20/hr	$16.20/hr	$16.20/hr

1 In addition to loading/unloading and driving time, hauls of greater than 160 one-way miles have layover hours (varying by distance) added.

2 Includes driver's annual wage, labor overhead, capital recovery charges, insurance, taxes, administrative costs, and profit.

3 Includes costs for fuel, oil, tires, maintenance, and repairs.

TABLE 4-8. PRICE ESTIMATES FOR COMMERCIAL HAZARDOUS WASTE TRANSPORTATION

One-Way Mileage	$/One-Way Mile - by Waste Type		
	Bulk Solids	Bulk Liquids	Containerized Liquids or Solids
25	5.19	7.72	8.74
50	4.21	5.61	5.91
100	3.72	4.55	4.50
250	4.26	4.81	4.46
500	4.16	4.60	4.17

4.2.2 Landfill Prices

Price estimates have been prepared for the landfill disposal of solid hazardous wastes. Two price estimates are given to account for price variations for waste in which free liquids are present and must be solidified. EPA regulations state that waste containing free liquids must not be placed in a landfill. Therefore, containers holding free liquids must have all such liquid solidified with absorbent so that liquid is no longer observed.

Landfill disposal price estimates are reported in dollars per ton for wastes with no free liquids (i.e., bulk and containerized solids) and wastes with free liquids (i.e., bulk liquids and containerized liquids/sludges) that require solidification prior to disposal. These price ranges and typical price estimates, which are shown in Table 4-9, are based on the following key assumptions:

- cost estimates are based on commercial capacity, personnel, and equipment and operating requirements;
- landfill annual capacities range from 16,500 tons to 135,000 tons;
- landfill operating life is 20 years (20 cells);
- landfill has a double-lined containment system (synthetic membrane and clay) with leachate collection and removal;
- landfill cover system is double-lined (synthetic membrane and clay); and
- estimated unit costs of disposal ($/ton) are increased 100 percent to reflect commercial disposal prices.

Resulting price estimates were compared to reported values from an EPA-sponsored survey of the commercial hazardous waste industry in 1984 and current prices being charged by a commercial vendor.

4.2.3 Incineration Prices

Prices for commercial hazardous waste incineration are highly variable due to pricing structures based on waste type (liquids, solids, sludges), packaging (bulk or containerized), waste characteristics (percent halogen, moisture con-

TABLE 4-9. PRICE ESTIMATES FOR COMMERCIAL HAZARDOUS WASTE LANDFILL DISPOSAL

No Free Liquids Present

Waste Type	Range ($/ton)	Typical Price ($/ton)
Bulk solids	75-150	100
Containerized sludges/solids	125-275	200

Free Liquids Present (solidification required)

Waste Type	Range ($/ton)	Typical Price ($/ton)
Bulk liquids	175-250	200
Containerized liquids/sludges	225-375	300

tent, BTU value, viscosity), and quantity of residuals generated after incineration (ash, scrubber sludge). A range of prices, as well as a typical price, for commercially incinerating various waste types have been estimated and is presented in Table 4-10. These price estimates are reported in dollars per ton and were obtained through EPA-sponsored survey efforts conducted in 1984. The typical estimates reported reflect current (1986) prices being charged, based on price information provided by a commercial vendor.

4.2.4 Deep Well Injection Prices

Prices charged for deep well injection generally vary with the toxicity of the waste, amount of solids in the waste stream, and the degree of pretreatment required prior to injection. A range of prices for deep well injection for two different waste streams is presented in Table 4-11 both in dollars per gallon and dollars per ton. A typical price in 1986 dollars is also estimated.

4.2.5 Land Treatment Prices

Prices for commercial land treatment vary according to waste type and hazardous constituent concentration, as well as the soil type and the capacity of the treatment facility. A range of prices for commercial land treatment is presented in Table 4-12. A typical price in 1986 dollars is also presented. It should be noted that this method of treatment is available only for a limited number of waste types. The waste streams that are most typically land treated include oily sludges, gum and wood products, and some organics.

4.2.6 Treatment Prices

Prices for commercial treatment of waste are highly variable and waste stream specific. The presence of cyanides, heavy metals, or highly toxic constituents in waste is a reflected by a substantial price increase for treatment. A range of prices for waste treatment for three types of waste streams is presented in Table 4-13. These figures are reported both in dollars per gallon and dollars per ton. A typical price in 1986 dollars is also presented.

TABLE 4-10. PRICE ESTIMATES FOR COMMERCIAL HAZARDOUS WASTE INCINERATION

Type of Waste	Type of Incinerator	Range ($/ton)	Typical Price ($/ton)
Bulk liquids	Liquid injection	100-900	500
Bulk solids	Rotary kiln	500-1,500	1,000
Containerized liquids (liquid portion only	Liquid injection	150-1,100	625
Containerized solid/sludges	Rotary kiln	500-1,500	1,000

TABLE 4-11. PRICE ESTIMATES FOR COMMERCIAL HAZARDOUS WASTE DEEP WELL INJECTION

Waste Type	Price Range ($/gal)	Price Range ($/ton)	Typical Price ($/ton)
Oily wastewaters	0.07-0.28	17-67	50
Toxic wastewaters (requiring pretreatment)	0.50-1.20	120-288	250

TABLE 4-12. PRICE ESTIMATES FOR COMMERCIAL HAZARDOUS WASTE LAND TREATMENT

Waste Type	Price Range ($/gal)	Price Range ($/ton)	Typical Price ($/ton)
All wastes that can be land treated	0.02-0.09	5-22	20

TABLE 4-13. PRICE ESTIMATES FOR COMMERICAL HAZARDOUS WASTE TREATMENT

Waste Type	Price Range ($/gal)	Price Range ($/ton)	Typical Price ($/ton)
Acidic or alkaline wastes	0.06-0.85	14-204	100
Leachate, contaminated run-off, moderately toxic wastes	0.40-1.00	96-240	200
Cyanides, heavy metals, highly toxic wastes	0.85-6.00	204-1,441	500

CHAPTER 5

EQUIPMENT AND FACILITY DECONTAMINATION

Sections 264.114 and 265.114 of 40 CFR require, as part of closure, that all facility equipment and structures be properly disposed of or decontaminated by removing all hazardous wastes and residues. This chapter presents the unit costs for equipment and facility decontamination conducted by third-party personnel. Costs for excavating contaminated materials and disposing of remaining hazardous wastes and residues are presented in the chapters entitled "Demolition and Excavation" and "Inventory and Residual Management," respectively. For more information on equipment and facility decontamination refer to EPA/600/2-85/028 March 1985, Guide for Decontaminating Buildings, Structures, and Equipment at Superfund Sites.

5.1 EQUIPMENT DECONTAMINATION

5.1.1 Heavy Equipment

Unit costs for the decontamination of heavy equipment are calculated by considering third-party labor costs, steamcleaner rental cost, and hourly operating cost. These unit costs are presented in Table 5-1. Residual is generated at the rate of 100 gallons per hour. Treatment and disposal of residuals are discussed in Chapter 4, "Inventory and Residual Management."

5.1.2 Pumps and Feed Lines

Unit costs for decontaminating pumps and feed lines consist of the time required for both set-up and mixing the cleaning solution (usually alkaline) and final rinsing with water. The base time for set-up, mixing, and cleaning of a pump and its associated line is eight hours. For each additional pump (and line) another four hours are required. The volume of cleaning fluid and rinse water required for each pump and line is estimated at 50 gallons. This document assumes that the cleaning fluid and rinse water will be treated as a hazardous

TABLE 5-1. HEAVY EQUIPMENT DECONTAMINATION

Equipment	Decontamination Time (hrs)	Unit Cost ($/piece)
Forklift	1	26
Rotary disc	1	26
Tractor	2	52
Tank wagon	2	52
Front-end loader	3	79
Dozer	3	79
Backhoe	3	79
Front shovel	3	79

waste. Treatment and disposal costs for these residuals are presented in the chapter entitled "Inventory and Residual Management." Table 5-2 presents the costs for decontamination and the residual quantities generated for up to four pumps and lines.

5.2 FACILITY DECONTAMINATION

5.2.1 Tanks and Other Facility Structures

These include tank interiors, the interstitial space between double-walled steel tanks, vault system interiors, sumps or troughs, waste pile foundations, and other areas where wastes were managed. Concrete or asphalt slabs which will remain in place should also be decontaminated. Residuals generated from cleaning of facility structures are assumed to be treated as hazardous wastes. Tank cleaning costs are estimated in dollars per unit area. To assist the user in estimating tank cleaning costs, Table 5-3 presents a summary of surface areas compared with tank capacities for vertical and horizontal tanks ranging in size from 5000 to 30,000 gallons.

The following three cleaning methods and unit costs are considered appropriate for decontamination of tanks and other facility structures:

- Steamcleaning - an average of 50 square feet of surface area is cleaned per hour at a cost of $0.55 per square foot. Residual is generated at a rate of approximately four gallons per square foot.
- High-pressure washing - an average of 40 square feet of surface area is cleaned per hour at a cost of of $0.88 per square foot. Residual is generated at a rate of approximately four gallons per square foot.
- Sandblasting (dry system) - an average of 50 square feet of surface area is cleaned per hour at a cost of $0.62 per square foot. Residual is generated at a rate of approximately two pounds per square foot.

Management of decontamination residues is discussed in Chapter 4, "Inventory and Residual Management."

TABLE 5-2. PUMP AND FEED LINE DECONTAMINATION

Number of Pumps and Feed Lines	Decontamination Time (hrs)	Decontamination Cost ($)	Volume of Fluid Generated (gal)
One	8	212	50
Two	12	304	100
Three	16	396	150
Four	20	488	200

TABLE 5-3. SURFACE AREAS FOR VARIOUS TANK CAPACITIES

Typical Vertical Tank Dimensions

Capacity (gal)	Approximate Diameter (ft)	Approximate Height (ft)	Surface Area (ft^2)*
5,000	9	10.5	424
10,000	11.5	13	575
15,000	13	15	745
20,000	15	15	884
25,000	16	17	1,055
30,000	17	18	1,188

Typical Horizontal Tank Dimensions

Capacity (gal)	Approximate Diameter (ft)	Approximate Length (ft)	Surface Area (ft^2)*
5,000	6	23	490
10,000	8	26	750
15,000	8	29	1,080
20,000	10	34	1,225
25,000	10	38	1,350
30,000	11	42	1,640

* Includes top and bottom.

In addition, protective clothing and safety equipment are necessary for personnel involved in decontamination procedures. A cost of $80 per person is estimated and includes a splash suit, shoe covers, apron, gloves, goggles, respirator (half-mask with air purifying cartridges), and hard hat. This cost would be applicable for all decontamination activities except interior tank cleaning when it is necessary to enter the tank. If tank entry is anticipated, another four hours per tank and additional safety equipment are required. Labor costs are $23.00 per hour. The additional equipment replaces the half-mask respirator with a chest style, full-face respirator and organic vapors/acid gas canister at an additional cost of $172 per person.

The cost of bulk tank cleaning operations can vary significantly due to health and safety considerations. The unit costs discussed above for tank cleaning may be considerably understated depending on the degree of hazard expected when tank entry is necessary. It is quite conceivable that additional protective clothing, a self-contained breathing apparatus, and other safety procedures (i.e., buddy system, organic vapor monitors, emergency equipment, etc.) will be necessary. Incremental health and safety costs for bulk tank cleaning may add from 100 to 300 percent to the cost of normal (non-hazardous) cleaning operations. If hazardous working conditions are anticipated and the cost estimate does not adequately address worker health and safety considerations, a 200 percent surcharge should be included.

5.2.2 Tanks and Vaults Left in Place

Underground tanks can be removed and salvaged after decontamination or they can be left in place. If they are left in place they may be filled with sand. If the underground tank is contained in a vault system, the vault system may also be filled with sand. However, in both of these cases filling with sand is not a regulatory cost. If an underground tank is left in place and the tank is closed as a landfill, the tank would be filled with sand in order to provide structural integrity for the landfill cover. Similarly, if the underground tank is contained in a vault system and the tank is closed as a landfill, both the tank and the vault would be filled with sand to provide structural integrity for the landfill cover. In both of these cases filling with sand would be a regula-

tory cost. The unit cost for this procedure, including sand and labor, is $0.10 per gallon of tank and vault capacity.

5.2.3 Tank Removal

Three types of tanks can be used for treatment or storage of hazardous wastes. The three types are onground (aboveground), inground, and underground. Refer to Figures 1-13 of the preamble of the proposed tank rules in the Federal Register, Vol. 50, No. 123, June 26, 1985, pp. 26465-26481 for examples of these three types of tanks and their secondary containment systems. Onground and underground tanks are typically constructed of steel or fiberglass, while inground tanks are generally constructed of concrete.

Tanks are generally removed under the following circumstances: if the secondary containment system is contaminated; if necessary to remove contaminated soil; and for onground tanks if the tank area is closed as a landfill.

In order to remove inground tanks or underground tanks in a vault system a cover may need to be removed. The cost for cover removal can vary depending on the cover material, size, and type of seal. A small cover can be moved with a backhoe or front-end loader. Generally, there is no cost for moving a small cover because the backhoe or front-end loader would typically be on-site, and hooking the cover and moving it would only require a few minutes time. A large cover would typically be moved with a crane. A jackhammer may also be needed to loosen the cover before moving. Cover removal with a crane and jackhammer can range from $150-$300/hr plus $200 for mobilization/demobilization. A typical time and unit cost for moving a cover is 1 hour at $200/hr plus $200 for mobilization/demobilization. Concrete vaults with a cast-in-place cover will require cover demolition to remove the tank(s). Unit costs for concrete demolition are estimated at $3.70/$ft^2$ of cover surface area.

Some underground tanks may be covered with soil. In order to remove the tank, the soil must be excavated. Unit costs for soil excavation are presented in Chapter 6, "Demolition and Excavation."

Onground shop fabricated steel or fiberglass tanks less than 700 ft^2 in surface area are loosened from a concrete pad with a jackhammer or cut from steel supports and moved off the pad with a crane. Field erected steel tanks greater than 700 ft^2 in surface area are loosened from a concrete pad with a jackhammer or cut from steel supports, cut into sections with a cutting torch, and set aside with a crane. The unit costs for moving tanks are presented in Table 5-4. To assist the user in estimating tank surface area, Table 5-3 presents a summary of surface areas for vertical and horizontal tanks ranging in capacity from 5,000 to 30,000 gallons. The user should note that the worksheet allows only one line for tank surface area for tanks being removed. On the worksheet the surface area is multiplied by a unit cost selected from Table 5-4 to estimate the total tank removal cost. If more than one tank is to be removed, the user must determine one surface area to represent each of the tanks being removed before selecting a unit cost from Table 5-4. If the user does not select a unit cost which is representative of tank size, an incorrect removal cost would be calculated. For example, if three tanks at 100 ft^2/tank were to be removed, the user would enter 300 ft^2 on the worksheet for tank surface area. The appropriate unit cost from Table 5-4 would be \$5.80/ft^2 because the surface area of each tank is 100 ft^2. The tank removal cost would be \$5.80/ft^2 x 300 ft^2 = \$1740.

Inground tanks are removed by demolition with a hydraulic hammer attached to a backhoe. Some work may have to be done manually with a jackhammer. The demolition unit cost for mesh reinforced concrete is \$76/yd^3, while for rod reinforced concrete it is \$105/yd^3. Demolished concrete located below grade is typically truck loaded with a backhoe. Unit costs for truck loading of demolished concrete are presented in Table 6-1 of Chapter 6.

Underground tanks are removed with a crane. In some cases the tank must be cut loose from supports before lifting. The unit costs for moving tanks are presented in Table 5-4. Similar to onground tanks, the user must select a unit cost that represents the average surface area of all the tanks being removed.

In areas where an underground tank will be subjected to water conditions the tank may be anchored to a concrete slab or deadman. The slab may or may not

TABLE 5-4. UNIT COSTS - TANK REMOVAL

Tank Surface Area (ft^2)	Unit Cost ($/$ft^2$)(a)(b)
100	5.80
150	4.00
275	2.50
425	1.80
680	1.30
>700	2.20

(a) For onground tanks if site is congested or small working area add up to 100 percent to the unit cost.

(b) For underground tanks if site is congested or small working area add up to 200 percent to the unit cost.

need to be removed with the tank depending on whether the soil surrounding the slab has been contaminated. If contamination has not reached beyond the anchor slab the anchor straps are cut, the tank is removed, and the slab is left in place.

The unit costs for demolition of a concrete slab or deadman and the unit costs for loading the demolished concrete with a backhoe are presented in Chapter 6, "Demolition and Excavation."

5.2.4 Container Rinsing

The unit cost for triple rinsing empty 55-gallon containers with a sprayer is estimated as $32.75 per hour. This cost includes labor, equipment, and operating costs. Drums are assumed to be cleaned at a rate of five minutes per drum. Container rinsing generates an estimated 10 gallons of residual per drum. The cost of cleaning solutions is negligible and is therefore not included in these estimates.

5.2.5 Incinerator Refractory Removal

The cost for removing the refractory (fire brick) from the primary combustion chamber of an incinerator is estimated at $3.20 per square foot of surface area. Costs for rubble disposal must be added as found under Chapter 4, "Inventory and Residual Management." The incinerator refractory weighs approximately 33 pounds per square foot of surface area.

5.2.6 Off-Site Management of Rinsed Containers

Rinsed containers may be disposed of in a sanitary landfill. Tipping fee costs for sanitary landfills are assumed to be $12/ton.

5.2.7 Demonstrating Success of Decontamination

The success or adequacy of decontamination of facility structures and equipment must be evaluated. The level of decontamination necessary to satisfy the

closure performance standard will serve as the benchmark for determining decontamination success. The structure or equipment must be cleaned, washed, and/or rinsed as many times as necessary to achieve a contaminant concentration in the last rinse water equal to that of the closure performance standard. Costs associated with determining the success of decontamination include the cost to collect rinse water samples and to determine the concentration of the hazardous constituents in the rinse water. Costs for determining the concentration of hazardous constituents are the same as the contract lab fees for groundwater quality analysis found in the chapter entitled "Monitoring and Testing".

CHAPTER 6

DEMOLITION AND EXCAVATION

The demolition and removal of facility structures and the excavation of soils, containment systems, and subsoils may be required to properly decontaminate and close the facility. This chapter presents the unit costs and assumptions used in developing cost estimates for the removal of contaminated facility structures and soils by independent site work contractors.

6.1 PAD OR FOUNDATION DEMOLITION

Unit costs to breakup and load a concrete or bituminous pad vary with pad thickness, accessibility, and equipment selected to perform the task. Demolition of reinforced foundations up to six inches thick using power equipment (i.e., a backhoe loader with a hydraulic hammer) costs approximately $23.50 per cubic yard. Reinforced foundations ranging from seven to 24 inches thick, on the otner hand, cost $105 per cubic yard to remove. If hand-held air equipment must be used, the demolition costs for mesh reinforced foundations range from $76 to $87 per cubic yard. We estimate that the typical cost for contaminated pad removal is $82 per cubic yard, based on expected pad thickness, relatively small job size, and accessibility that may limit the use of power equipment. Unit costs for truck loading of the demolished pad are presented in Table 4-4 of the chapter entitled "Inventory and Residual Management."

If concrete or asphalt slabs are cracked or damaged, the soil beneath them may be contaminated. This requires that soil samples be taken beneath such areas. This can be accomplished by core drilling through the slab at a cost of $15 per inch of slab thickness. Sample testing costs are found in Chapter 2, "Monitoring and Testing." If contamination is found, the slab should be opened to remove the contaminated soil.

6.2 EXCAVATION OF CONTAMINATED SOILS AND CONTAINMENT SYSTEMS

Surface soils, impoundment sediments, containment liners, vault systems, and subsoils contaminated by exposure to waste materials through spills, leaks, and long-term containment (e.g., a primary liner) will require management as a hazardous waste. If contamination is suspected at the site, a cost for soil testing should be included in the closure cost estimate to verify and determine the extent of existing contamination (see chapter entitled "Monitoring and Testing" for appropriate unit costs). Once the contaminated materials have been excavated, costs for transport and disposal will also be incurred. Unit cost guidance for transport and disposal services is provided in the chapter entitled "Inventory and Residual Management."

Three methods of excavation are presented for removal of surface soils, impoundment sediments, containment liners, and subsoils: hydraulic backhoe, front shovel, and a dozer coupled with a front-end loader. Each method of excavation includes truck loading but not transportation costs. The unit costs for excavation using each equipment type under varying soil conditions are summarized in Table 6-1. The individual unit costs for excavation are presented in Figures 6-1 through 6-4.

Vault systems are a type of secondary containment system for underground tanks. Vault systems are removed by demolition of the concrete walls. The vault walls must be broken up with a hydraulic hammer attached to a backhoe. The demolition unit cost for mesh reinforced concrete walls is $\$76/yd^3$ and for rod reinforced concrete walls it is $\$105/yd^3$. Demolished concrete located below grade is typically truck loaded with a backhoe. Unit costs for truck loading of the demolished vault walls are presented in Table 6-1.

New onground (aboveground) tanks can be supported by a concrete ringwall located below grade next to the external liner system. If the secondary containment system must be removed and contaminated soils beyond the secondary containment system must be removed, it would be necessary to remove the concrete ringwall. The demolition and truck loading cost would be the same as for a vault system.

TABLE 6-1. UNIT COSTS - EXCAVATION OF CONTAMINATED SOILS

Cost ranges by soil type	Unit Costs ($/yd^3)	Mobilization/ Demobilization Costs ($)
• soft soil or sand	1.07 - 3.91	NA*
• medium soil	1.26 - 4.60	NA
• clay or heavy soil	2.02 - 7.36	NA
Cost ranges by equipment type		
• backhoe	1.42 - 7.36	140 - 390
• front shovel	1.07 - 5.33	140 - 340
• dozer with track mounted front-end loader	1.79 -11.28	188 - 340
• dozer with wheel mounted front-end loader	1.69 -11.69	160 - 355
Average costs for medium soil		
• backhoe	2.91	230
• front shovel	2.10	210
• dozer with track mounted front-end loader	4.14	255
• dozer with wheel mounted front-end loader	4.17	255

* NA - not applicable; mobilization/demobilization costs depend on heavy equipment type, not soil type.

FIGURE 6-1. UNIT COSTS OF EXCAVATING WITH A BACKHOE

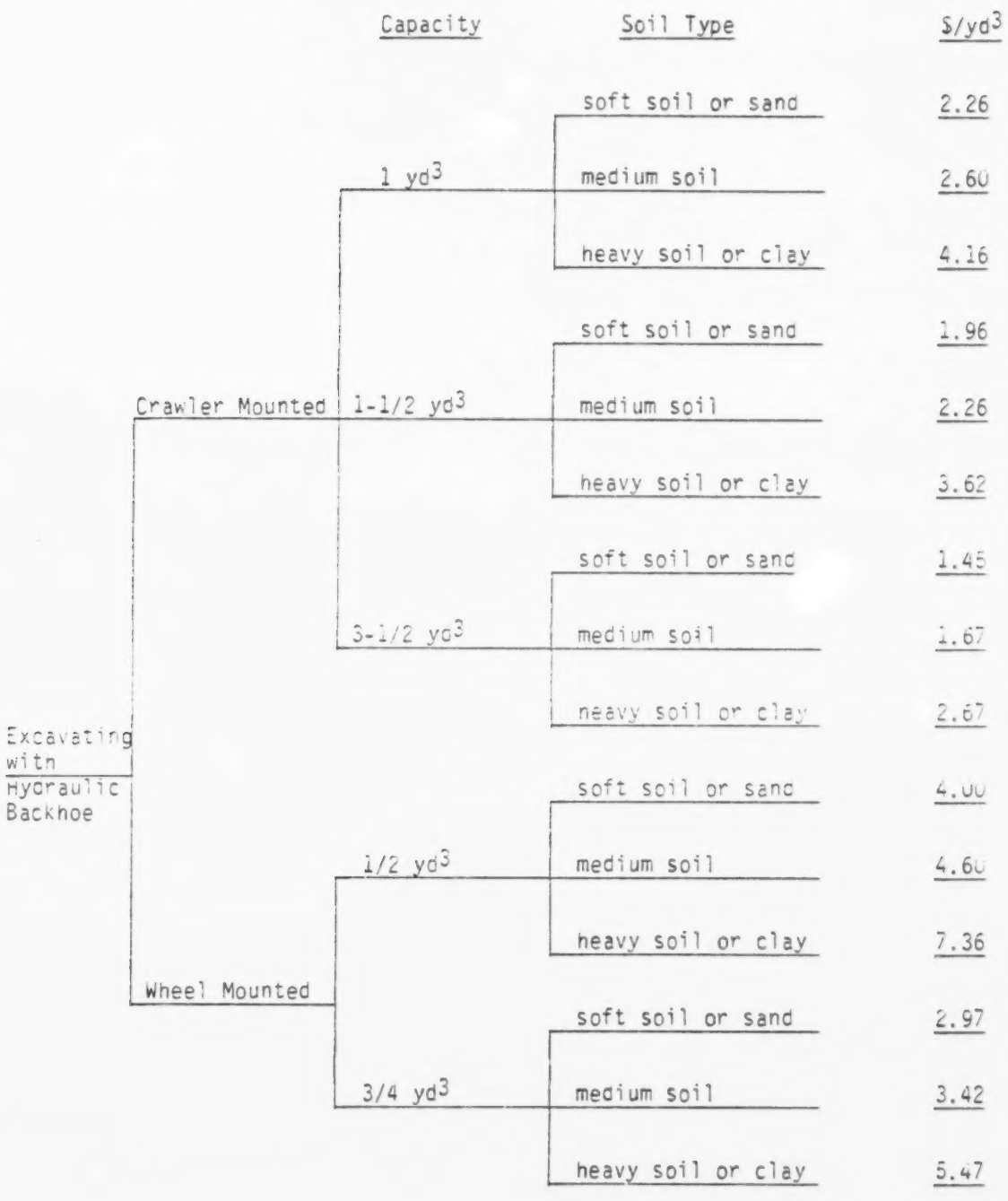


FIGURE 6-2. UNIT COSTS OF EXCAVATING WITH A FRONT SHOVEL

	Capacity	Soil Type	$/yd^3
Excavating with Front Shovel	1/2 yd^3	soft soil or sand	2.90
		medium earth	3.33
		heavy soil or clay	5.33
	3/4 yd^3	soft soil or sand	1.99
		medium earth	2.29
		heavy soil or clay	3.66
	1 yd^3	soft soil or sand	1.80
		medium earth	2.07
		heavy soil or clay	3.31
	1-1/2 yd^3	soft soil or sand	1.35
		medium earth	1.55
		heavy soil or clay	2.48
	3 yd^3	soft soil or sand	1.10
		medium earth	1.26
		heavy soil or clay	2.02

FIGURE 6-3. UNIT COSTS OF EXCAVATING IN COMMON EARTH WITH A DOZER

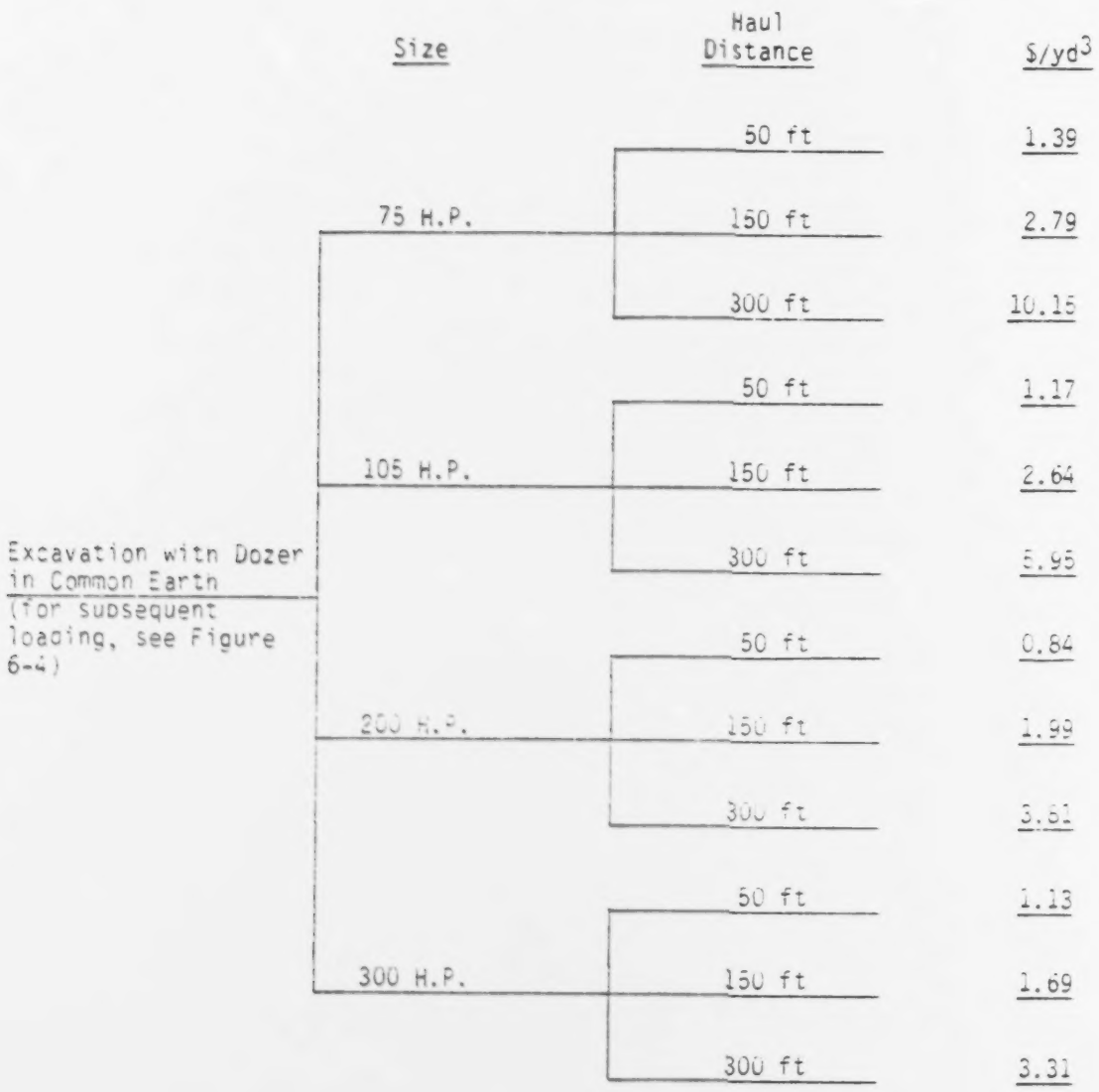
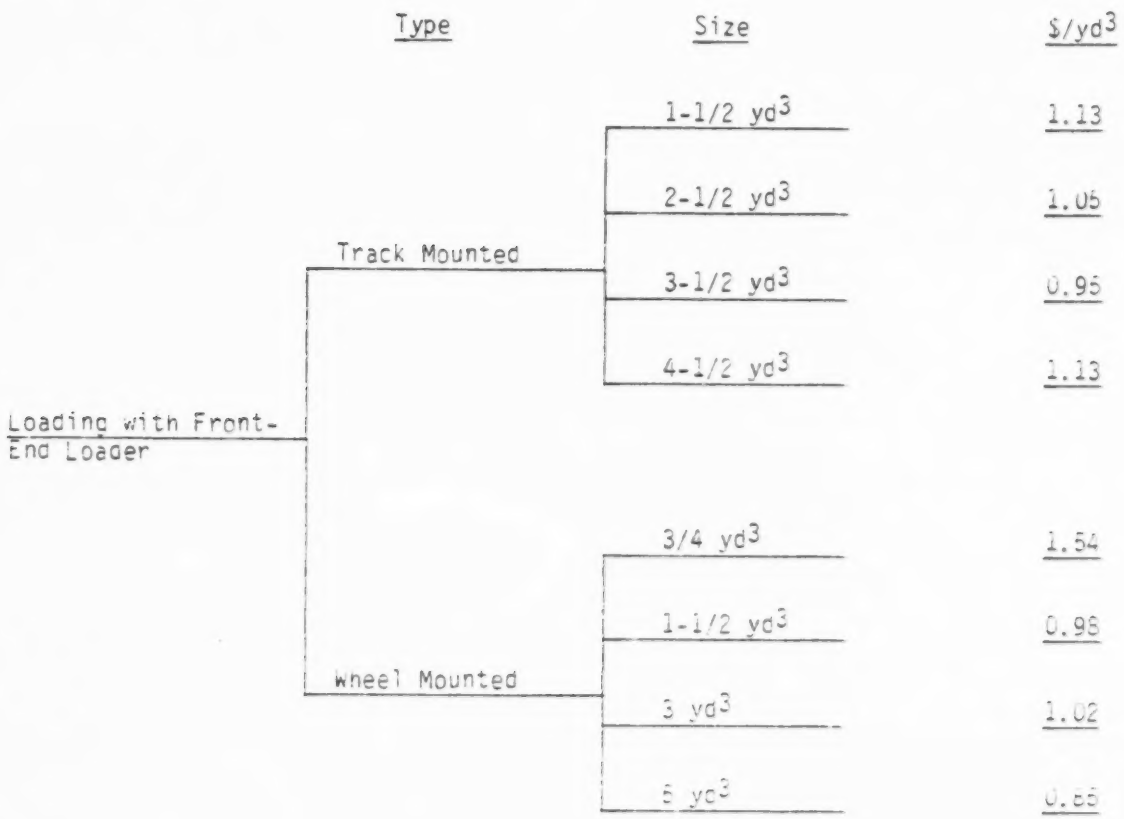


FIGURE 6-4. UNIT COSTS FOR LOADING WITH A FRONT-END LOADER



6.3 OTHER COSTS

6.3.1 Mobilization/Demobilization of Heavy Equipment

This cost is added by the site work contractor to transport heavy equipment to and from the site. Mobilization/demobilization costs apply to both demolition and excavation if heavy equipment is used. The range and average cost for each equipment type are shown in Table 6-1. Additional detail on mobilization/demobilization costs for specific sizes of heavy equipment is provided in Chapter 4, "Inventory and Residual Management."

6.3.2 Protective Clothing and Safety Equipment

Workers involved in demolishing and excavating contamianted materials should be provided with appropriate clothing. A cost of $77 per person is estimated and includes total body coveralls, gloves, goggles, respirator (half-mask), and hard hat.

6.3.3 Heavy Equipment Decontamination

After completion of demolition and excavation activities the contractor's equipment must be decontaminated. Unit cost estimates for equipment decontamination have been prepared by equipment type and appear in Table 5-1 of the chapter entitled "Equipment and Facility Decontamination." Management of decontamination residues is discussed in Chapter 4, "Inventory and Residual Management."

6.3.4 Surcharge for Handling Contaminated Materials

A surcharge may be added by the site contractor either to the unit cost of demolition/excavation (i.e., cost per cubic yard) or to the total job cost to account for increased insurance (liability and medical) premiums, higher wages for personnel, equipment modifications, safety equipment, and personnel training. A surcharge, if applied, will usually add 75 to 150 percent to the

cost of normal excavation activities, depending on the degree of hazard existing at the site. We estimate a typical surcharge for contaminated material excavation to add 100 percent to the base cost.

CHAPTER 7

FINAL COVER AND REVEGETATION

7.1 REGULATORY REQUIREMENTS

Parts 264 and 265 of the RCRA regulations require final cover and revegetation as part of closure for land disposal facilities. Specifically, Sections 264.310 and 265.310 require that all landfills have a final cover. Sections 264.228 and 265.228 require, for surface impoundments in which wastes are left in place at closure, that: 1) the wastes be solidified or stabilized to a bearing capacity sufficient to support a cover; and 2) a landfill cover that meets the requirements of Sections 264.310 or 265.310 be placed over the waste. Sections 264.258 and 265.258 require that waste piles in which not all contaminated subsoils can be practicably removed or decontaminated after all reasonable efforts, be closed according to the landfill closure requirements. Section 264.280 requires that land treatment facilities must establish a vegetative cover (unless the level of hazardous constituents in the treatment zone soil does not exceed background), and Section 265.280 requires that land treatment facilities must have a final cover that controls infiltration, erosion, run-off, and wind erosion.

Sections 264.221 and 264.301 require that each new surface impoundment and landfill, each new unit at an existing facility, each replacement of an existing unit, and each lateral expansion of an existing unit must have two or more liners. Sections 265.221 and 265.301 require that each new unit, replacement of an existing unit, or lateral expansion of an existing unit receiving wastes after May 8, 1985 must have two or more liners. EPA has specified the two liner system to consist of a top synthetic liner and a lower recompacted clay liner. The preamble to the July 15, 1985 regulations states that each double-lined cell must be closed with an equivalent cap implying a synthetic liner and clay layer. Landfills and surface impoundments regulated by Part 265 regulations which ceased receiving waste beginning May 8, 1985 do not have to have any liners. Consequently, either a single clay or single synthetic liner in the cap is sufficient.

All Part 264 and Part 265 landfills and surface impoundments receiving wastes after May 8, 1985 would need to have a final cover consisting of the following layers in ascending order from the layer closest to the waste.

(1) Native soil which is used to bring the active area to the appropriate grade and establish a foundation for the final cover.

(2) Clay layer to provide long-term minimization of precipitation infiltration and leachate generation.

(3) Synthetic membrane to avoid the build-up of liquids in a closed cell and to provide short-term prevention of infiltration.

(4) Drainage layer with tiles to promote drainage of the final cover. A sand drainage layer is recommended because gravel could puncture the synthetic membrane. Three types of drainage tile can be used: PVC, concrete, or vitrified clay.

(5) Geotextile filter fabric which is placed on top of the drainage layer to prevent clogging of the drainage tiles.

(6) Topsoil which is used to support vegetation.

(7) Revegetation which provides ground cover to minimize soil erosion. Revegetation consists of seeding, fertilizing and mulching.

A final cover for a Part 265 landfill or surface impoundment which ceased receiving wastes beginning May 8, 1985 but has not been closed would consist of the following layers in ascending order from the layer closest to the waste.

(1) Native soil which is used to bring the active area to the appropriate grade and establish a foundation for the final cover.

(2) Low-permeability layer which consists of either clay or a synthetic membrane. If the facility is located on a site that contains clay, the facility would probably use on-site clay as the low-permeability layer in the cover. If a facility is not located on a site that contains clay, but is located near an off-site source of clay, the facility would probably use off-site clay as the low-permeability layer in the cover. A synthetic membrane would be used as a low-permeability layer instead of clay when the cost for materials, transportation, and installation of a synthetic membrane is cheaper than the cost for materials, transportation, and placement of off-site clay.

(3) Drainage layer with tiles to promote drainage of the final cover. If a synthetic membrane is used in the final cover, the drainage layer should be composed of sand. A gravel layer could puncture

the syntnetic membrane. If only clay is used in the final cover, either sand or gravel would be suitable for the drainage layer. Three types of tile can be used in the drainage layer: PVC, concrete, or vitrified clay.

(4) Topsoil which is used to support vegetation.

(5) Revegetation which provides ground cover to minimize soil erosion. Revegetation consists of seeding, fertilizing, and mulching.

The RCRA regulations do not specify thicknesses for the sand, gravel, and soil layers in the final cover. Recommended minimum thicknesses are presented in Table 7-1.

7.2 UNIT COSTS

This section presents the unit costs for final cover and revegetation. All final cover and revegetation costs are third party costs.

7.2.1 Native Soil for Slope and Fill

Native soil is used to bring the site to grade and establish a foundation for the remaining cover layers. It was assumed that the shape of the cover foundation formed by the native soil is a pyramid with a three percent slope on each side of the pyramid. This shape will promote maximum drainage of the cover and prevent ponding. If the volume of soil needed for slope and fill is unknown, the following equation should be used to give an approximation of the volume of native soil needed for slope and fill:

$$V = \frac{0.03\ w^2\ (l - \frac{w}{3})}{4}$$

where: V = volume (yd^3)
w = the width of area to be capped (yd)
l = the length of area to be capped (yd)

TABLE 7-1. RECOMMENDED FINAL COVER LAYER THICKNESSES

Material	Minimum Thickness
On-site clay	2 ft (0.67 yd)
Off-site clay	2 ft (0.67 yd)
Sand	1 ft (0.33 yd)
Gravel	1 ft (0.33 yd)
Topsoil	2 ft (0.67 yd)
Crushed stone	1 ft (0.33 yd)

The unit cost for native soil for slope and fill consists of costs for excavation of the soil with a dozer, placement and spreading of the excavated soil with a grading scraper, and compaction of the placed soil with a sheepsfoot roller. The excavation costs for native soil vary depending on the characteristics of the soil to be excavated. Native soil unit costs are presented for three different types of soil: soil with sand and gravel characteristics, soil with common earth characteristics, and soil with clay characteristics. These unit costs and a typical unit cost are summarized in Table 7-2. The individual unit costs based on various equipment and soil factors are presented in Figures 7-1 through 7-3.

When soils are excavated and handled they increase in volume, or swell, because of an increase in voids (air space). Compaction factors are used to account for this material swelling when determining the volume of in-place soil required. Table 7-3 shows the compaction factors for soil materials. The compaction factor is added to one and multiplied by the soil material unit cost. For example, the typical native soil unit cost, including the compaction factor, is: $5.77/yd^3 \times 1.25 = \$7.21/yd^3$.

7.2.2 On-Site Clay

Table 7-1 presents a minimum thickness for on-site clay for determining the volume of clay required in the final cover if volume is not specified in the closure plan. The thickness shown in Table 7-1 would comply with the RCRA regulations for a landfill cover.

The unit cost for on-site clay consists of costs for excavation of the clay with a dozer, placement and spreading of the excavated clay with a grading scraper, and compaction with a sheepsfoot roller. A range of on-site clay unit costs and a typical on-site clay unit cost are summarized in Table 7-4. Figure 7-4 presents individual on-site clay unit costs based on different equipment factors. Table 7-3 shows the recommended compaction factor for on-site clay. (See the "Native Soil" section for an explanation of compaction factors.)

As the clay cap is being installed, each lift should be tested for moisture content and density before proceeding to the next lift. Lifts are typically 6

TABLE 7-2. UNIT COSTS - NATIVE SOIL FOR SLOPE AND FILL

Cost ranges by soil type	Unit Costs ($/yd^3)
• sand and gravel	3.31 - 6.48
• common earth	3.48 - 6.80
• clay	4.24 - 8.37
Typical unit costs	
• excavation	2.48
• placement/spreading	2.25
• compaction	1.04
Typical total unit cost	5.77

FIGURE 7-1. UNIT COSTS - NATIVE SOIL FOR SLOPE AND FILL WITH SAND AND GRAVEL CHARACTERISTICS

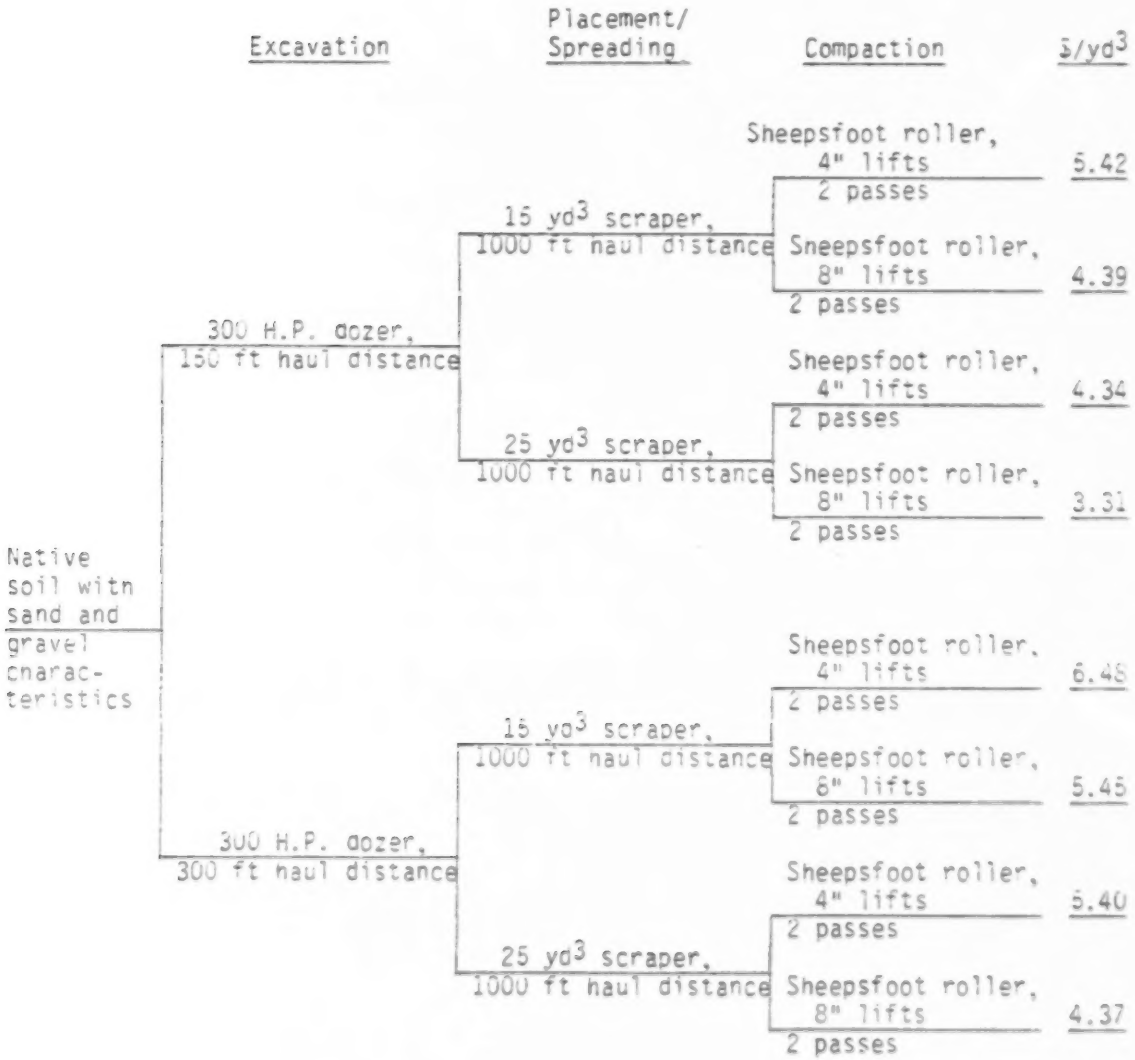

Excavation
Placement/ Spreading
Compaction
$/yd3
Native soil with sand and gravel characteristics
300 H.P. dozer, 150 ft haul distance
15 yd3 scraper, 1000 ft haul distance
25 yd3 scraper, 1000 ft haul distance
300 H.P. dozer, 300 ft haul distance
15 yd3 scraper, 1000 ft haul distance
25 yd3 scraper, 1000 ft haul distance
Sheepsfoot roller, 4" lifts 2 passes
5.42
Sheepsfoot roller, 8" lifts 2 passes
4.39
Sheepsfoot roller, 4" lifts 2 passes
4.34
Sheepsfoot roller, 8" lifts 2 passes
3.31
Sheepsfoot roller, 4" lifts 2 passes
6.48
Sheepsfoot roller, 8" lifts 2 passes
5.45
Sheepsfoot roller, 4" lifts 2 passes
5.40
Sheepsfoot roller, 8" lifts 2 passes
4.37

FIGURE 7-2. UNIT COSTS - NATIVE SOIL FOR SLOPE AND FILL WITH COMMON EARTH CHARACTERISTICS

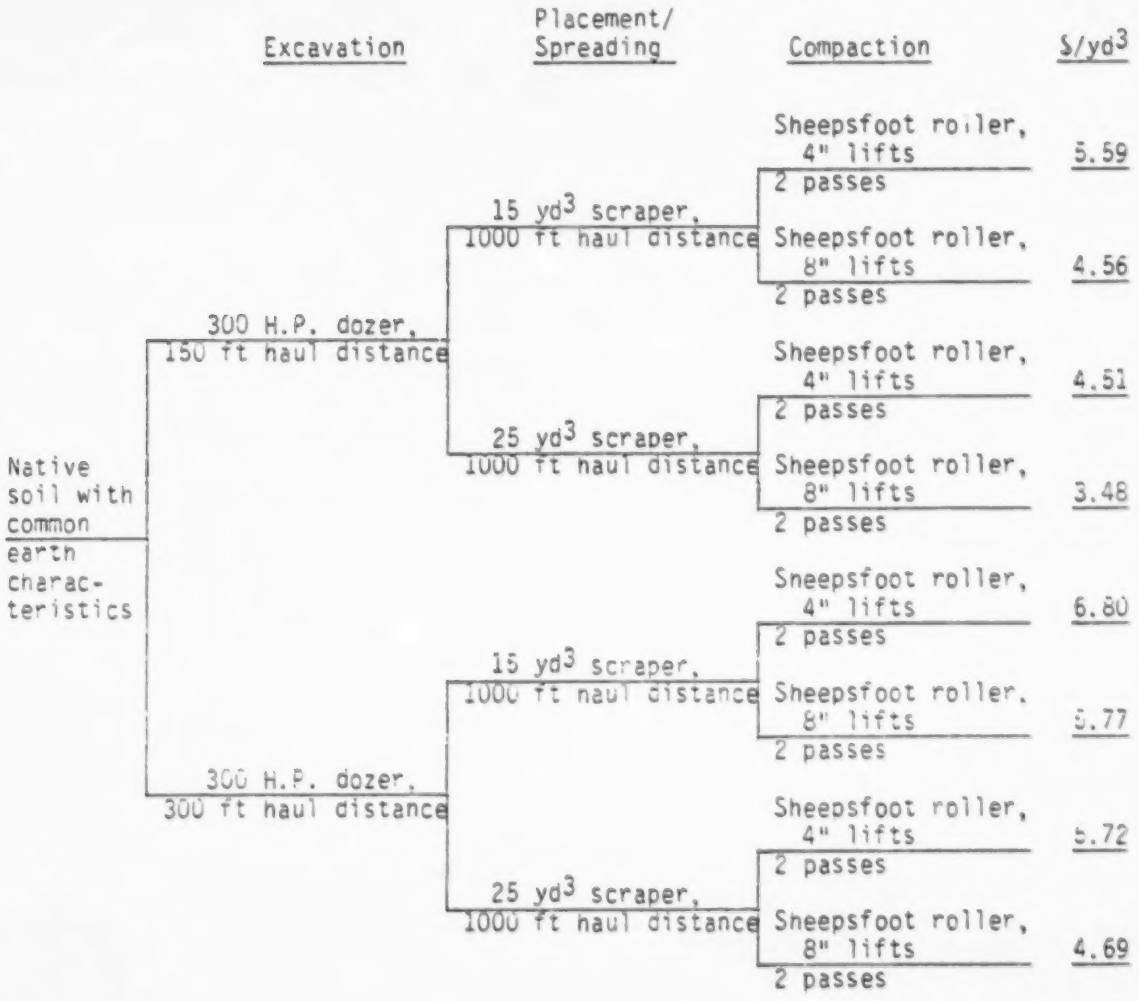

Excavation
Placement/ Spreading
Compaction
$/yd3
Native soil with common earth charac-teristics
300 H.P. dozer, 150 ft haul distance
300 H.P. dozer, 300 ft haul distance
15 yd3 scraper, 1000 ft haul distance
25 yd3 scraper, 1000 ft haul distance
15 yd3 scraper, 1000 ft haul distance
25 yd3 scraper, 1000 ft haul distance
Sheepsfoot roller, 4" lifts 2 passes
5.59
Sheepsfoot roller, 8" lifts 2 passes
4.56
Sheepsfoot roller, 4" lifts 2 passes
4.51
Sheepsfoot roller, 8" lifts 2 passes
3.48
Sheepsfoot roller, 4" lifts 2 passes
6.80
Sheepsfoot roller, 8" lifts 2 passes
5.77
Sheepsfoot roller, 4" lifts 2 passes
5.72
Sheepsfoot roller, 8" lifts 2 passes
4.69

FIGURE 7-3. UNIT COSTS - NATIVE SOIL FOR SLOPE AND FILL WITH CLAY CHARACTERISTICS

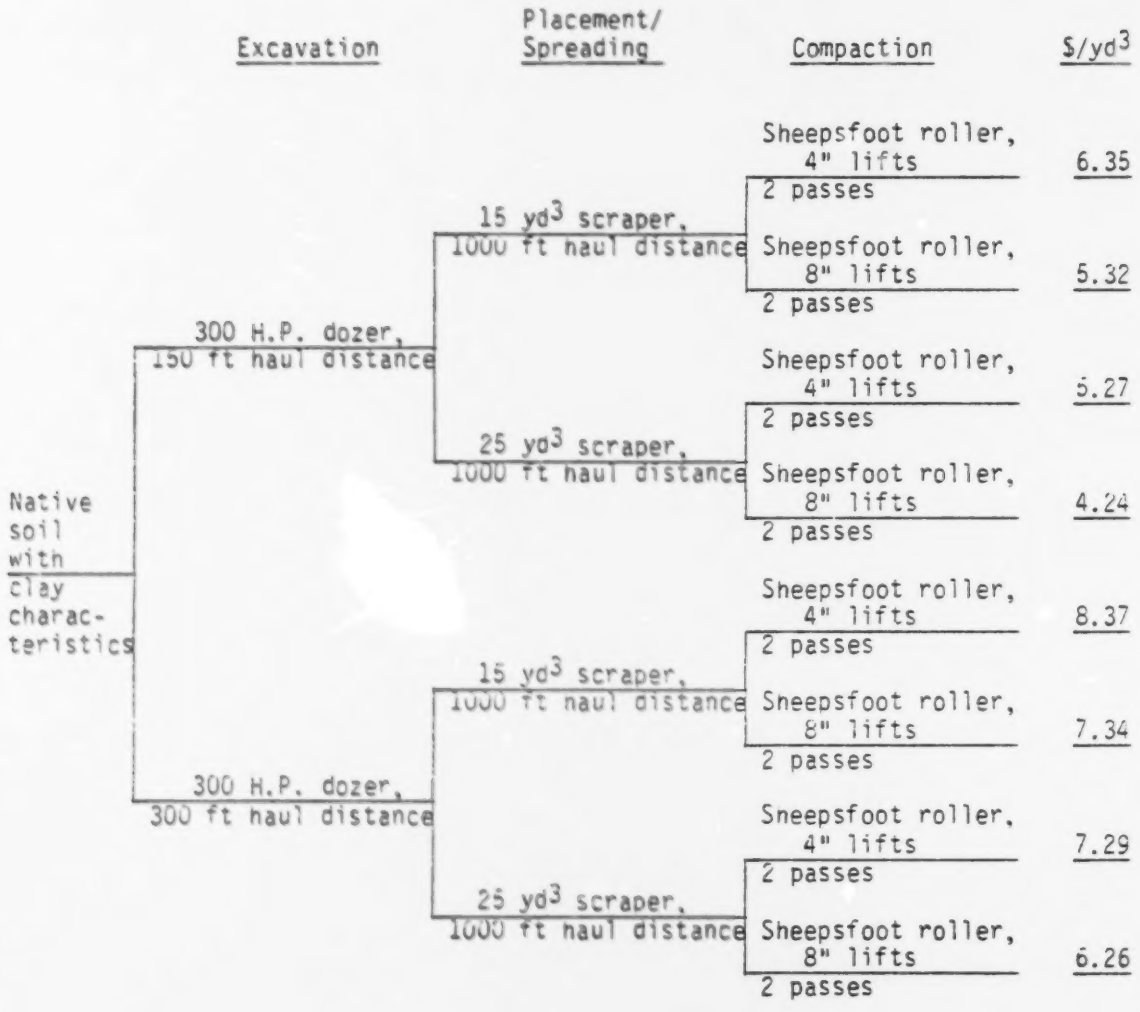

Excavation
Placement/ Spreading
Compaction
$/yd3
Native soil with clay characteristics
300 H.P. dozer, 150 ft haul distance
300 H.P. dozer, 300 ft haul distance
15 yd3 scraper, 1000 ft haul distance
25 yd3 scraper, 1000 ft haul distance
15 yd3 scraper, 1000 ft haul distance
25 yd3 scraper, 1000 ft haul distance
Sheepsfoot roller, 4" lifts 2 passes
6.35
Sheepsfoot roller, 8" lifts 2 passes
5.32
Sheepsfoot roller, 4" lifts 2 passes
5.27
Sheepsfoot roller, 8" lifts 2 passes
4.24
Sheepsfoot roller, 4" lifts 2 passes
8.37
Sheepsfoot roller, 8" lifts 2 passes
7.34
Sheepsfoot roller, 4" lifts 2 passes
7.29
Sheepsfoot roller, 8" lifts 2 passes
6.26

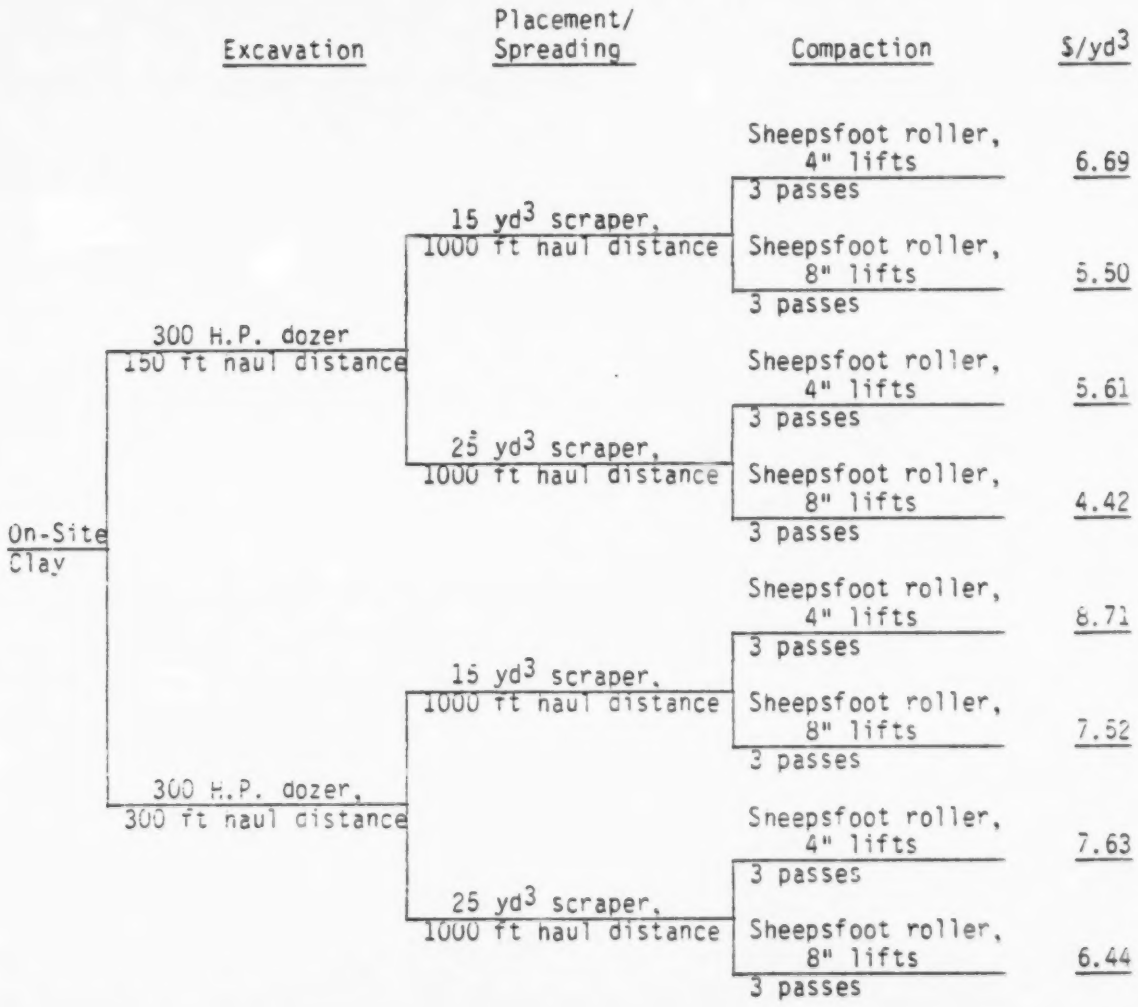
TABLE 7-3. COMPACTION FACTORS FOR SOIL MATERIALS

Material	Typical Factors
Native soil for slope and fill	0.25
Topsoil	0.25
Sand	0.10
Gravel	0.05
On-site clay	0.25
Off-site clay	0.40
Crushed stone	0.05

TABLE 7-4. UNIT COSTS - ON-SITE CLAY

	Unit Costs ($/yd^3)
Cost range	4.42 - 8.71
Typical unit costs	
• excavation	4.05
• placement/spreading	2.25
• compaction	2.41
Typical total clay unit cost	8.71

FIGURE 7-4. UNIT COSTS - ON-SITE CLAY



to 8 inches thick (0.17 - 0.22 yd). For final cover areas < 5 acres, two samples per lift are recommended. For final cover areas ≥ 5 acres, three samples per lift are recommended. The unit cost for clay testing is $230/sample. This includes testing for moisture content, permeability, proctor compaction, and labor.

7.2.3 Off-Site Clay

Table 7-1 presents a minimum thickness for off-site clay for determining the volume of clay required in the final cover if a volume is not specified in the closure plan. The thickness shown in Table 7-1 would comply with the RCRA regulations for a landfill cover.

The unit cost for off-site clay consists of costs for purchase of the clay, delivery to the land disposal facility, spreading the dumped clay with a dozer, and compaction with a sheepsfoot roller. The purchase price for off-site clay that is suitable for a hazardous waste land disposal facility cover is variable. Clay costs can range from $4.75 to $14.50 per cubic yard depending on the properties of the clay and the amount of processing needed to make the clay suitable for a land disposal facility cover. One source cited a purchase cost of $4.75 per cubic yard for a suitable clay located in the northeast U.S. which needed minimal processing. Another source cited a purchase cost of $12 to $14 per cubic yard for a Georgia clay which required some processing to derive the necessary properties to make it suitable for a land disposal cover. We assume a typical cost to be $4.75 per cubic yard. Table 7-5 presents a list of delivery unit costs for a range of distances. A range of off-site unit costs and a typical off-site clay unit cost are summarized in Table 7-6. Figure 7-5 presents individual off-site clay unit costs based on various haul distances and equipment factors. Table 7-3 shows the compaction factor for off-site clay. (See the "Native Soil" section for an explanation of compaction factors.)

As the clay cap is being installed, each lift should be tested for moisture content and density before proceeding to the next lift. Lifts are typically 6 to 8 inches thick (0.17 - 0.22 yd). For final cover areas <5 acres, two samples per lift are recommended. For final cover areas ≥ 5 acres, three samples per lift are recommended. The unit cost for clay testing is $230/sample. This includes testing for moisture content, permeability, proctor compaction, and labor.

TABLE 7-5. UNIT COSTS - DELIVERY

Distance	Unit Cost ($/yd^3)
1-mile round trip	1.56
2-mile round trip	1.95
3-mile round trip	2.32
4-mile round trip	2.61
5-mile round trip	3.64
10-mile round trip	4.60
20-mile round trip	6.50
50-mile round trip	10.16

TABLE 7-6. UNIT COSTS - OFF-SITE CLAY

	Unit Costs ($/yd^3)
Cost range	
• purchase	4.75 - 14.50
• total cost	9.61 - 18.35 [1]
Typical unit costs	
• purchase	4.75
• delivery (50-mile round trip)	10.16
• spreading	1.03
• compaction	2.41
Typical total unit cost	18.35

1 The total cost range assumes a purchase cost of $4.75/yd^3.

FIGURE 7-5. UNIT COSTS - OFF-SITE CLAY

Purchase	Delivery Distance	Compaction	$/yd^3
Off-Site Clay (includes purchase and spreading)	4-mile round trip	Sheepsfoot roller, 4" lifts, 3 passes	10.80
		Sheepsfoot roller, 8" lifts, 3 passes	9.61
	20-mile round trip	Sheepsfoot roller, 4" lifts, 3 passes	14.69
		Sheepsfoot roller, 8" lifts, 3 passes	13.50
	50-mile round trip	Sheepsfoot roller, 4" lifts, 3 passes	18.35
		Sheepsfoot roller, 8" lifts, 3 passes	17.16

7.2.4 Synthetic Membrane

A 30-mil synthetic membrane is the minimum thickness synthetic membrane recommended which would comply with the RCRA regulations for a landfill cover. The most typical type of 30-mil synthetic membrane used in a final cover is polyvinyl chloride (PVC).

The unit cost for a synthetic membrane consists of costs for purchase, delivery, and installation. Installation includes rollout and spreading, anchoring, and field seaming. Table 7-7 gives both a range of unit costs for purchase, delivery, and installation and a typical unit cost for a 30-mil synthetic membrane.

Prior to adding the remaining layers of the final cover, the synthetic membrane should be visually inspected for punctures and the field seaming should be tested by a different contractor than the contractor who installed the membrane. A typical cost for this activity is 25 percent of the total membrane cost.

7.2.5 Gravel

Table 7-1 presents a minimum thickness for a gravel drainage layer for determining the volume of gravel required in the final cover if a drainage layer volume is not specified in the closure plan. The thickness shown in Table 7-1 would comply with the RCRA regulations for a landfill cover.

The unit cost for gravel consists of costs for purchase of the gravel, delivery to the land disposal facility, spreading the dumped gravel with a dozer, and compaction with a sheepsfoot roller. A range of gravel unit costs and a typical gravel unit cost are summarized in Table 7-8. Figure 7-6 presents individual gravel unit costs based on various haul distances and equipment factors. Table 7-3 shows the compaction factor for gravel. (See the "Native Soil" section for an explanation of compaction factors.)

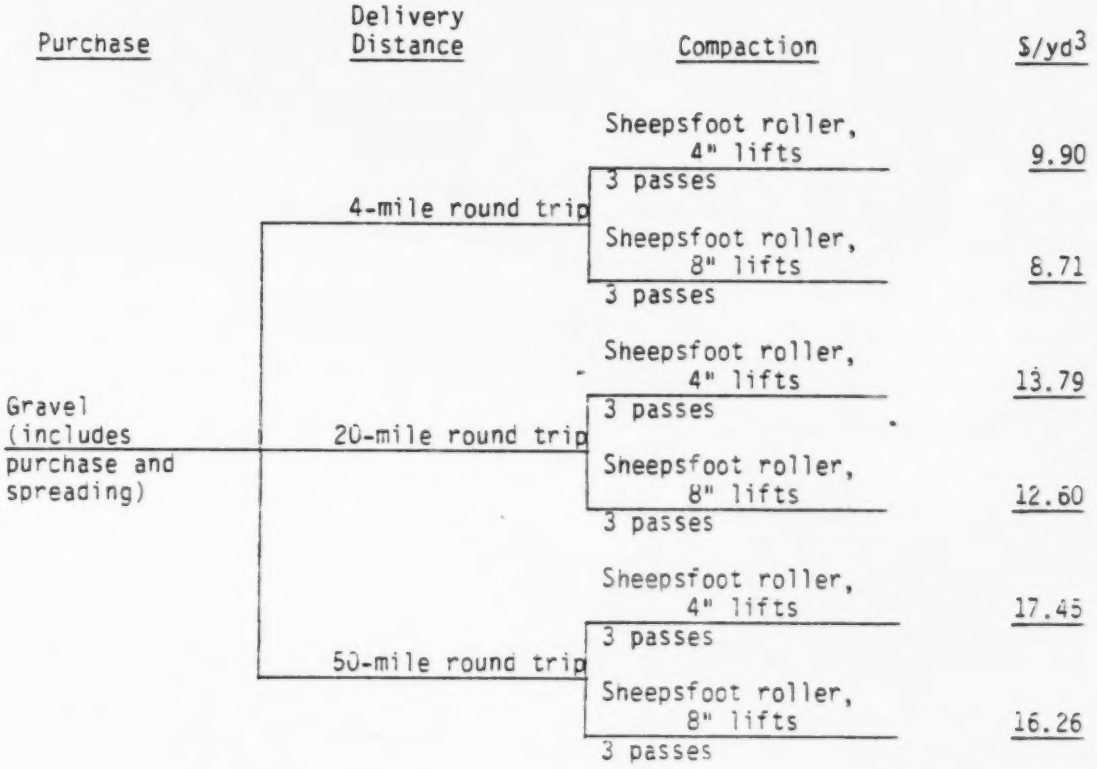
TABLE 7-7. UNIT COSTS - 30-MIL PVC SYNTHETIC MEMBRANE

Unit cost ranges	Unit Costs ($/yd^2)
• purchase	1.62 - 4.50
• delivery	0.09 - 0.45
• installation	0.36 - 0.54
• total	2.07 - 5.49
Typical unit costs	
• purchase	2.60
• delivery	0.25
• installation	0.50
Typical total unit cost	3.35

TABLE 7-8. UNIT COSTS - GRAVEL

	Unit Costs ($/yd^3)
Cost range	8.71 - 17.45
Typical unit costs	
o purchase	3.85
o delivery (4-mile round trip)	2.61
o spreading	1.03
o compaction	1.22
Typical total unit cost	8.71

FIGURE 7-6. UNIT COSTS - GRAVEL



7.2.6 Sand

Table 7-1 presents a minimum thickness for a sand drainage layer for determining the volume of sand required in the final cover if a drainage layer volume is not specified in the closure plan. The thickness shown in Table 7-1 would comply with RCRA regulations for a landfill cover.

The unit cost for sand consists of costs for purchase of the sand, delivery to the land disposal facility, spreading the dumped sand with a dozer, and compaction with a riding vibrating roller. A range of sand unit costs and a typical sand unit cost are summarized in Table 7-9. Figure 7-7 presents individual sand unit costs based on various haul distances and equipment factors. Table 7-3 shows the compaction factor for sand. (See the "Native Soil" section for an explanation of compaction factors.)

7.2.7 Drainage Tile

Drainage tiles are placed in the sand or gravel drainage layer to collect precipitation that infiltrates the cover. Drainage tiles are placed end-to-end around the perimeter of the drainage layer.

The unit cost for drainage tile consist of the tile cost (including delivery and excavating a trench in which to place the tile), backfilling, and compaction. Unit costs for three types of tile are presented: PVC, vitrified clay, and concrete. PVC unit costs and a typical drainage tile unit cost are summarized in Table 7-10. The unit cost for the three types of tile are presented in Figure 7-8.

7.2.8 Geotextile Filter Fabric

A geotextile filter fabric cost is incurred for a Part 264 landfill cover. The geotextile filter fabric is placed on top of the drainage layer to prevent clogging of the drainage tiles.

The unit cost for a geotextile filter fabric consists of purchase, delivery, and installation costs. Table 7-11 lists both a range of unit costs for

TABLE 7-9. UNIT COSTS - SAND

	Unit Costs ($/yd^3)
Cost range	9.88 - 18.18
Typical unit costs	
o purchase	5.50
o delivery (4-mile round trip)	2.61
o spreading	1.03
o compaction	1.49
Typical total unit cost	10.63

FIGURE 7-7. UNIT COSTS - SAND

Purchase	Delivery Distance	Compaction	$/yd^3
Sand (includes purchase and spreading)	4-mile round trip	Vibrating roller, 6" lifts, 3 passes	10.63
		Vibrating roller, 12" lifts, 3 passes	9.86
	20-mile round trip	Vibrating roller, 6" lifts, 3 passes	14.52
		Vibrating roller, 12" lifts, 3 passes	13.77
	50-mile round trip	Vibrating roller, 6" lifts, 3 passes	16.18
		Vibrating roller, 12" lifts, 3 passes	17.43

TABLE 7-10. UNIT COSTS - DRAINAGE TILE

	Unit Costs ($/L.F.)
Cost range	1.06 - 3.54
Typical unit costs	
• PVC tile	0.50
• trenching and backfilling	0.56
Typical total unit cost	1.06

FIGURE 7-8. UNIT COSTS - DRAINAGE TILE

Tile	Size	Trenching and Backfilling	$/ft
PVC	4" diameter (includes delivery)	6" wide, 12" deep	1.06
	6" diameter (includes delivery)	8" wide, 12" deep	1.75
Concrete	4" diameter (includes delivery)	6" wide, 12" deep	2.10
	6" diameter (includes delivery)	8" wide, 12" deep	2.33
Vitrified Clay	4" diameter (includes delivery)	6" wide, 12" deep	2.38
	6" diameter (includes delivery)	8" wide, 12" deep	3.54

TABLE 7-11. UNIT COSTS - GEOTEXTILE FILTER FABRIC

Quantity of Filter Fabric Needed (yd^2)	Unit Cost Ranges		
	Purchase ($/$yd^2$)	Delivery ($/$yd^2$)	Installation ($/$yd^2$)
1,210 - 2,420	0.65 - 0.95	0.05	0.08 - 0.10
2,420 - 4,840	0.60 - 0.90	0.05	0.08 - 0.10
4,840 - 9,680	0.57 - 0.85	0.05	0.08 - 0.10
9,680 - 24,200	0.54 - 0.80	0.05	0.08 - 0.10
24,200 - 53,240	0.51 - 0.70	0.05	0.08 - 0.10
> 53,240	0.44 - 0.63	0.05	0.08 - 0.10

Typical unit costs

- purchase $ 0.69/yd^2
- delivery $ 0.05/yd^2
- installation $ 0.09/yd^2

Typical total unit cost $ 0.83/yd^2

purchase, delivery, and installation based on the quantity of fabric needed and a typical unit cost for a geotextile filter fabric.

7.2.9 Topsoil

Table 7-1 presents a minimum thickness for a topsoil layer for determining the volume of topsoil required in the final cover if a topsoil volume is not specified in the closure plan. The thickness shown in Table 7-1 would comply with the RCRA regulations for a landfill cover.

The unit cost for topsoil consists of costs for purchase of the topsoil, delivery to the land disposal facility, spreading the dumped topsoil with a dozer, and compaction with a sheepsfoot roller. A range of topsoil unit costs and a typical topsoil unit cost are summarized in Table 7-12. Figure 7-9 presents topsoil unit costs based on various haul distances and equipment factors. Table 7-3 shows the compaction factor for topsoil. (See the "Native Soil" section for an explanation of compaction factors.)

7.2.10 Crushed Stone

In arid regions of the country crushed stone may be preferred to vegetation for controlling erosion. Crushed stone is preferred over sand because it is not easily dispersed by wind and will not wash away if there is a rainfall event. If crushed stone is selected instead of vegetation, the topsoil layer would be omitted. Table 7-1 presents a minimum thickness for a crushed stone layer for determining the volume of stone required in the final cover if a stone volume is not specified in the closure plan. The thickness shown in Table 7-1 would comply with the RCRA regulations for a landfill cover.

The unit cost for crushed stone consists of costs for purchase of the stone, delivery to the land disposal facility, spreading the dumped stone with a dozer, and compaction with a sheepsfoot roller. A range of crushed stone unit costs and a typical crushed stone unit cost are summarized in Table 7-13. Figure 7-10 presents individual crushed stone unit costs based on various haul distances and equipment factors. Table 7-3 shows the compaction factor for crushed stone. (See the "Native Soil" section for an explanation of compaction factors.)

TABLE 7-12. UNIT COSTS - TOPSOIL

	Unit Costs ($/yd^3)
Cost range	11.42 - 20.16
Typical unit costs	
• purchase	6.56
• delivery (4-mile round trip)	2.61
• spreading	1.03
• compaction	1.22
Typical total unit cost	11.42

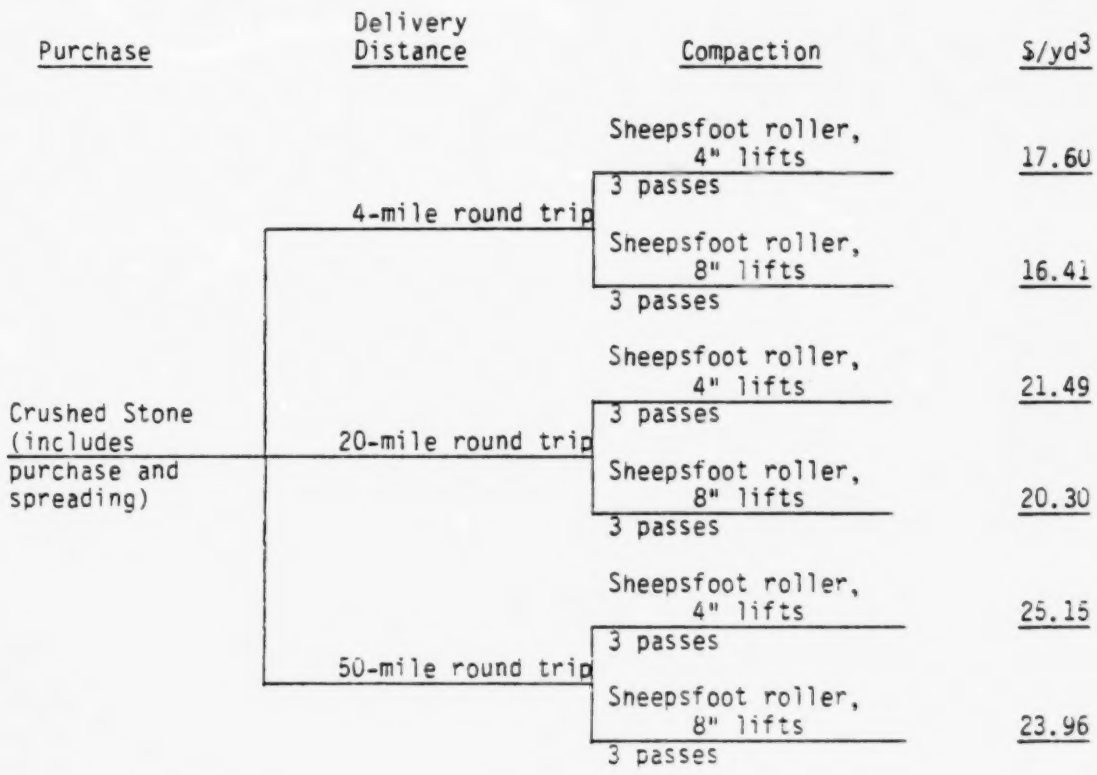
FIGURE 7-9. UNIT COSTS - TOPSOIL

Purchase	Delivery Distance	Compaction	$/yd3
Topsoil (include purchase and spreading)	4-mile round trip	Sheepsfoot roller, 4" lifts, 3 passes	12.61
		Sheepsfoot roller, 8" lifts, 3 passes	11.42
	20-mile round trip	Sheepsfoot roller, 4" lifts, 3 passes	16.50
		Sheepsfoot roller, 8" lifts, 3 passes	15.31
	50-mile round trip	Sheepsfoot roller, 4" lifts, 3 passes	20.16
		Sheepsfoot roller, 8" lifts, 3 passes	18.97

TABLE 7-13. UNIT COSTS - CRUSHED STONE

	Unit Costs ($/yd^3)
Cost range	16.41 - 25.15
Typical unit costs	
• purchase	11.55
• delivery (4-mile round trip)	2.61
• spreading	1.03
• compaction	1.22
Typical total unit cost	16.41

FIGURE 7-10. UNIT COSTS - CRUSHED STONE



7.2.11 Revegetation

The cost for revegetation includes costs for soil preparation and grading, which consists of raking the topsoil layer; seeding at 261 pounds of seed per acre; fertilizing at 968 pounds of fertilizer per acre, liming at 0.5 to 2.5 tons per acre, and mulching with a one inch deep layer of oat straw. A range of seeding unit costs and a typical revegetation unit cost are summarized in Table 7-14. If revegetation is unlikely to be successful because the facility is located in an extremely arid climate, a layer of material such as gravel could be used to protect the cover and prevent wind dispersal of finer materials.

7.2.12 Mobilization/Demobilization

In addition to the unit costs for final cover and/or revegetation, a cost for mobilization/demobilization of heavy equipment should be included. A range of mobilization/demobilization costs and typical costs for final cover and revegetation are shown in Table 7-15.

TABLE 7-14. UNIT COSTS - REVEGETATION

	Unit Costs ($/acre)
Seeding cost ranges by application method	
• tractor spreader	401 - 2,004
• hydraulic spreader	562 - 2,165
Typical unit costs	
• soil preparation/grading	1002
• seeding	795
• fertilizer	176
• mulch	1048
• lime: initial application	214
supplementary application	60

TABLE 7-15. MOBILIZATION/DEMOBILIZATION COSTS

Cost ranges by equipment type	Cost ($)
• dozer	100 - 135
• self-propelled scraper	195 - 320
• riding vibrating roller	100 - 135
• sheepsfoot roller	100 - 135
• tractor	100 - 135
Typical cost	
• dozer	125
• self-propelled scraper	250
• riding vibrating roller	100
• sheepsfoot roller	100
• tractor	105
Typical total cost for final cover	
• 2 dozers at $125/dozer	250
• 1 scraper at $250/scraper	250
• 2 rollers at $100/roller	200
• Total	700
Typical total cost for revegetation	
• 1 tractor at $105/tractor	105

CHAPTER 8

CERTIFICATION OF CLOSURE AND POST-CLOSURE

Sections 264.115 and 265.115 of 40 CFR require certification by both the TSDF owner or operator and an independent registered professional engineer (or an independent qualified soil scientist for land treatment) when closure is completed. This helps ensure that the facility is closed in accordance with the specifications of the closure plan. Similarly, Sections 264.120 and 265.120 of 40 CFR require a certification, signed by the TSDF owner or operator and an independent registered professional engineer, that post-closure care was performed in accordance with the approved post-closure plan. The registered professional engineer or soil scientist may be either employed by a consulting firm or operating independently in their own business.

Some facility owner/operators may not close all facility components at the end of the facility's operating life, because parts of the facility (i.e., landfill cells, tanks, or other process units) may have been closed at various times over a period of years prior to final closure. The closures of parts of a facility prior to final closure are called partial closures. The RCRA regulations require that partial closures be certified for waste piles, surface impoundments, landfills, and land treatment units. Partial closures of tanks, incinerators, or containers, however, do not need to be certified. Certification of the partial closure of waste piles, surface impoundments, landfills, and land treatment is to be performed when the partial closure is complete. This is because it would be very difficult for an independent registered professional engineer to verify, at the time of final closure, that all partial closures were performed in accordance with an approved closure plan. Therefore, this section contains unit cost guidance for certification of both partial and final closures.

A review of closure cost estimates has shown that many facility owner/operators estimate the cost for certification of closure as a lump sum cost (e.g., $2000). Another approach to estimating certification costs is to base them on the professional engineer's time spent during the closure period.

The latter method provides a more detailed cost estimate and is used in this guidance document.

The labor rate ranges for personnel involved in closure and post-closure certification are presented in the "Labor Categories and Rates" chapter of this volume. Their typical labor rates are summarized in Table 8-1. All of the labor rates reflect the cost of having the work performed by a third party. The following sections contain methodologies for estimating costs for certification of partial closures, final closure, and post-closure.

8.1 CERTIFICATION OF PARTIAL CLOSURES

The time requirements for personnel involved in certifying partial closures will vary considerably, depending on the process unit that is being closed. The recommendations presented in this section are for frequency of inspections and estimates of the hours necessary for each inspection. They should be used only if no information on the number of inspections is provided in the closure plan. Table 8-2 contains the estimated personnel time requirements for certification of partial closures.

The independent registered professional engineer or soil scientist will likely conduct one to three visits per week for every week of the closure period. The time needed per visit would vary with the complexity of the closure activities; a reasonable range would be four to six hours per visit. This would include time for both inspection of closure activities and preparation of a brief status report on the facility. If the partial closure period lasts less than a week, at least one visit from the P.E. or soil scientist should be expected. The time needed per visit would vary with the complexity of the closure activities; a reasonable range would be four to six hours per visit (including status report). In addition to the time spent inspecting the closure activities, the professional engineer will require time to conduct a review of the closure plan drawings, and specifications before partial closure activities begin. It will also be necessary to prepare final documentation at the comple-

TABLE 8-1. TYPICAL LABOR RATES FOR CERTIFICATION PERSONNEL

Position	Labor Rate ($/hr)
Independent Registered Professional Engineer	
- with consulting firm	45.50
- not with consulting firm	75.00
Independent Qualified Soil Scientist	
- with consulting firm	45.50
- not with consulting firm	75.00
Clerical	18.00

TABLE 8-2. ESTIMATED CERTIFICATION TIME REQUIREMENTS

Personnel	Number of Visits/Inspections	Time Required (hrs)
• Partial Closures		
Independent Registered Professional Engineer or Soil Scientist	1-3/week	4-6 (per visit)*
Clerical	-	2-4/week*
• Final Closure		
Independent Registered Professional Engineer or Soil Scientist	1-3/week	4-8 (per visit)
Clerical	-	2-4/week
• Post-Closure		
Independent Registered Professional Engineer	2/year	4-8 (per visit)
Clerical	-	4 (per visit)

* These estimates are for each partial closure. At least one visit/inspection by the P.E. should be assumed for partial closures that last less than one week.

tion of the partial closure period certifying that the waste management unit has been closed in accordance with specifications in the approved closure plan. The time needed to review the closure plan is estimated at four hours, and four hours is recommended to prepare final documentation.

The time requirements for the clerical person are for report typing and recordkeeping. Clerical time would need to be included if the P.E. or soil scientist is operating independently in his or her own single-person business. Clerical time would be included in the hourly rate of a P.E. or soil scientist who is an employee of a larger consulting firm. We estimate that two to four hours of clerical time per week will be necessary for each partial closure.

8.2 CERTIFICATION OF FINAL CLOSURE

The lump sum certification costs in closure cost estimates we have reviewed ranged from less than one percent to ten percent of the total closure cost. The most common value was approximately three percent of the total closure cost. If information on time requirements is not provided in the closure plan, we estimate that the independent registered professional engineer or soil scientist will visit the facility approximately one to three times per week for four to eight hours per visit during each week of the closure period. This time estimate includes travel to and from the site, inspection time, and time to draft a short status report of the closure activities at the facility. The frequency and duration of the visits are dependent on the complexity and extent of the closure activities, and the degree to which contamination is present at the facility. A minimum of three visits from the P.E. or soil scientist should be expected to certify final facility closure. In addition to the time spent inspecting the closure activities, the professional engineer will require time to conduct a review of the closure plan drawings, and specifications before final closure activities begin. It will also be necessary to prepare final documentation at the completion of the closure period certifying that the facility has been closed in accordance with specifications in the approved closure plan. The time needed to review the closure plan is estimated at eight hours and four hours is recommended to prepare final documentation.

The clerical time required for recordkeeping, reporting, and accounting responsibilities in association with the certification process is estimated to be two to four hours per week for every week of closure. As with clerical time for partial closure certification, it does not need to be included if the P.E. or soil scientist is an employee of a consulting firm that is larger than a single-person business. A summary of the estimated personnel time requirements for certification of final closure is presented in Table 8-2.

8.3 CERTIFICATION OF POST-CLOSURE

The cost for certification of post-closure will be calculated in a similar manner to that for the certification of final closure but will allow greater time intervals between inspections. If information on time requirements is not provided in the post-closure plan, we estimate that an independent registered professional engineer will visit the facility twice a year for a minimum of four hours for each visit. This time estimate includes travel to and from the site, inspection time, and time to draft a short report on the status of the facility. In addition to the time spent inspecting the post-closure activities, the professional engineer will require time to conduct a review of the post-closure plan and specifications before post-closure activities begin. It will also be necessary to prepare final documentation at the completion of the post-closure period certifying that the waste management unit has been managed in accordance with specifications in the approved post-closure plan. The time needed to review the post-closure plan is estimated at four hours, and four hours is recommended to prepare final documentation.

The clerical time required for recordkeeping, reporting, and accounting responsibilities in association with the certification process is estimated to be four hours per visit. Clerical time does not need to be included if the P.E. is an employee of a consulting firm that is larger than a single-person business. Table 8-2 presents estimated personnel time requirements for certification of post-closure.

SECTION 9

LABOR CATEGORIES AND RATES

This chapter presents third-party personnel and subcontracted labor rates used for both closure and post-closure activities. The descriptions of the necessary personnel and estimates of their labor rates are presented as separate subsections for closure and for post-closure care.

9.1 CLOSURE LABOR CATEGORIES AND RATES

Closure is assumed to be under the direction of an architectural/engineering firm, and all closure activities will be performed by third-party personnel as required in the RCRA regulations. Descriptions of these personnel are provided below. Costs for certain site work activities (e.g., final cover placement) are based on unit costs (e.g., $/cubic yard of topsoil) which include labor, materials, transportation, and equipment. A complete description of these activities and associated unit cost estimates can be found in the chapter of this volume entitled "Final Cover and Revegetation."

The following personnel will be required during the closure period:

- Consulting Engineer: supervision and planning of all closure activities
- Field Technician: inspections, monitoring, and sample collection
- Clerical: recordkeeping and reporting
- Equipment Operator: inventory handling and disposal
- Laborer: equipment and facility decontamination, repairs
- Draftsperson: preparation of isogram plan
- Process Operator: operation of incinerators, filter presses, and on-site treatment
- Land Surveying Team: plat surveying activities

- Attorney: submission of survey plat to local zoning authority

Labor rate estimates for these personnel are presented in Table 9-1. A range of annual base salaries was estimated along with a typical base salary for all of these personnel except the land surveying team and the attorney, whose services would be subcontracted out to private firms. Fringe benefits and the engineering firm's overhead were added to the base salaries of engineering firm personnel. These figures were then divided by annual person-hours (2080 hours per year) to arrive at the dollar-per-hour figures in the table.

Fringe benefits are usually estimated at 25 to 50 percent of the direct labor costs. This includes such things as pensions, holidays and vacations, sick leave, health and life insurance, disability insurance, social security, and unemployment taxes. The engineering firm's overhead or general works expense is usually estimated at 50 to 100 percent of the direct operating and labor costs. This includes such service functions as supervision of personnel, maintenance, security, accounting and purchasing, as well as fixed and variable costs on buildings and property in general use (e.g., offices, cafeterias, roads, parking lots, etc.).

Third-party laborers and equipment operators are assumed to be employed by a construction firm or site work contractor. The third-party process operator is assumed to be employed by a site clean-up contractor. Their dollar-per-hour cost includes fringe benefits and subcontractor's overhead and profit. Fringe benefits are assumed to be 25 percent of the labor costs. The subcontractor's overhead and profit is assumed to be 45 percent. This fee is added to labor costs which include fringe to arrive at the charged rates shown in the table.

9.2 POST-CLOSURE LABOR CATEGOIRES AND RATES

During the post-closure period, contracted labor will be used to provide post-closure care and maintenance. Descriptions of personnel and fees charged by an engineering firm to conduct these activities are presented in Table 9-2. A typical base salary for each individual directly employed by the engineering

TABLE 9-1. LABOR RATES AND FEES FOR CLOSURE

Personnel[1]	Base Range	Typical Base	$/Hour (range)[2]	$/Hour (typical)[3]
Consulting Engineer[4]	$37,000-$47,000/yr	$42,000/yr	40026-50.84	45.50
Field Technician	$17,000-$20,000/yr	$19,000/yr	18.39-21.63	20.50
Clerical	$16,000-$18,000/yr	$17,000/yr	17.31-19.47	18.00
*Heavy Equipment Operator[5]	$32,700-$34,700/yr	$33,700/yr	28.49-30.24	29.50
*Building/Construction Laborer[5]	$25,500-$28,500/yr	$26,500/yr	22.22-24.83	23.00
Draftsperson	$21,000-$23,000/yr	$22,000/yr	22.72-24.78	24.00
*Process Operator[5]	$29,000-$31,500/yr	$30,500/yr	25.71-27.45	26.50
Land Surveying Team	---	---	---	75.00
Attorney	---	---	---	100.00

[1] All personnel are employed by the firm conducting the closure with exception of those indicated with an asterisk (*).

[2] Includes fringe benefits (25% of base salary) and overhead (80%), except as noted.

[3] Rounded to nearest $0.50.

[4] Includes Registered Professional Engineer or Registered Soil Scientist working for a consulting firm.

[5] $/hour figures include fringe benefits (25%) and subcontractor's overhead and profit (45%).

TABLE 9-2. LABOR FEES FOR POST-CLOSURE

Personnel	Function	Typical Base Salary	Typical $/Hour Fee
Engineer	Inspections and administration	$42,000/yr	45.50
Field Technician	Inspections, monitoring, and sample collection	$19,000/yr	20.50
Secretary	Recordkeeping, reporting, and accounting	$17,000/yr	18.00
Laborer	Maintenance and repair of grounds and equipment	----	23.00
Process Operator	Operating on-site leachate treatment system	----	26.50
Attorney	Notation on property deed that the land has been used to manage hazardous waste and its use is restricted	----	100.00

firm (engineer, technician, secretary) is presented. For these individuals, fringe benefits, overhead, and profit were added and the resulting dollar-per-hour fee was derived. The engineering firm would subcontract to a local construction firm to obtain the services of laborer and to a site clean-up contractor to hire a process operator. In turn, a fee (profit) would be added by the engineering firm to the dollar-per-hour cost for the laborer or process operator. An attorney submits the waste record to the local land authority and puts the notice in the deed to the property (§§264.119/265.119). Such legal services would be subcontracted out to a private law firm.

CHAPTER 10

CLOSURE AND POST-CLOSURE INDIRECT COSTS

In addition to the direct costs of closure or post-closure such as inventory disposal, decontamination, final cover, groundwater monitoring, and maintenance, certain indirect costs are also incurred. Indirect costs, or fees as they are often called, are related to the design, construction, and testing of a system or facility. These costs are usually not explicitly included in the capital cost estimate, but are necessary to estimate the actual cost of a functional system or facility. The following sections describe each of the indirect costs and their application to preparing third party closure and post-closure cost estimates.

10.1 APPLICABILITY OF INDIRECT COSTS

Fees are frequently expressed as percentages of the direct capital cost estimate (i.e., equipment and material costs, installation labor costs, etc.). The type and range of fees vary on the basis of the technology or construction activity undertaken and the project's complexity and scale.

It should be noted that a project bid prepared by a general contractor is usually structured differently than that suggested in this guidance document. For instance, it is common for general contractors or subcontractors to include an allowance for overhead and profit in the amount charged for each yard of concrete or each hour of construction labor estimated. In some cases even direct costs such as equipment mobilization/demobilization are included in the material or labor unit cost bid amount. Furthermore, contractors may include an allowance for contingencies in their bid price, rather than list this item separately. In cases of high risk, however, contractors are likely to agree to perform only certain duties for the bid price and insist on a "cost-plus" clause to cover any items not specifically included in the bid.

For the purpose of this document, the method of estimating direct and indirect costs separately was selected. In this manner, the labor and material cost components necessary to complete a specific task can be estimated directly and are isolated from those expenses related to project management, scale and complexity, and uncertainity. Estimates of these indirect costs are made separately to account for the project's uniqueness and are added to the direct costs to derive a final budget amount. Therefore, no allowance for engineering and supervision, general contractor's overhead and profit, or contingency was included in the unit costs presented in this volume. The material and labor unit costs listed were estimated using subcontractors, and include overhead and profit on their labor, equipment, and materials used to complete each specified task.

In evaluating a third party closure or post-closure cost estimate, the reviewer should determine which items (if any) were estimated on the basis of a contractor's project bid. Costs estimated by a contractor are likely to include overhead and profit and a contingency but may not be listed separately in the total bid price. In these cases, no additional costs for the contractor's overhead and profit or contingency should be estimated. On the other hand, if the facility owner/operator prepared the cost estimate without obtaining any contractors' bids (or the reviewer is preparing a separate estimate using the worksheets in this guidance document), then an allowance for a contractor's overhead and profit and a contingency on the total cost of the project should be estimated separately as an indirect cost. The inclusion of an indirect cost for engineering and supervision may also be appropriate and is discussed in the following section of this chapter.

10.2 ENGINEERING AND SUPERVISION FEE

Facility closure following an approved closure plan will require little, if any, additional engineering from an engineering firm. The approved closure plan should already have sufficient architectural and engineering plans, drawings, and specifications to properly close the facility. Costs for minor design modi-

fications requiring an architect or engineer are included in the contingency fee, which is discussed later in this chapter. Closure administration, therefore, will likely be the responsibility of a general contractor who will schedule and coordinate the site work, hire appropriate subcontractors, and supervise, in conjunction with an independent professional engineer, all closure activities.

In cases in which the facility owner/operator has hired an engineering firm to coordinate closure or post-closure, the engineering firm will add their fee (including profit) to those closure or post-closure activities under their direction and management. This fee, which is referred to as engineering and supervision, is often billed as a percentage of the direct capital cost estimate for closure or post-closure care. Engineering fees typically include the costs associated with engineering design, drafting, construction and cost-estimation, field expense for construction supervision, home office expense (overhead), and project administration. This fee usually ranges from five to twenty percent of the direct capital costs of the project.

The fee charged depends on project scale (or size) and complexity. Small projects (in terms of job cost), projects which require considerable field supervision, projects with high degrees of uncertainty or risk, or projects which present unusual site conditions will result in higher engineering and supervision fees. In general, the percentage of the direct capital cost used to calculate this fee usually decreases slightly as the direct capital cost of the project increases. For example, projects less than $100,000 will result in fees of ten to fifteen percent, while high total project costs (i.e., in excess of one million dollars) will result in lower percentage fees, usually less than eight percent.

Facilities intending to hire an engineering firm to oversee closure or post-closure activities with existing, approved plans should expect a fee at the low end of the range (e.g., 5%) to cover supervisory and administrative expenses only. However, facilities which have not completed a closure (or post-closure) plan or, on the basis of EPA review will require substantial modifications to their existing plans, should include a fee of ten to fifteen percent of the clo-

sure and post-closure costs for engineering. In these cases, the engineering and supervisory fee should not be considered optional, because an engineering firm will need to prepare new (or revised) closure and post-closure documents.

10.3 CONTRACTOR'S FEE

When a general contractor coordinates construction and closure activities it will add overhead and profit as a percentage of the closure cost. The general contractor's profit for construction projects is typically estimated at ten percent of the direct costs. The contractor's overhead expense, however, is quite variable and dependent on job scale and location, competition, labor and equipment availability, and liability considerations. The range of the general contractor's overhead for construction projects is five to twenty percent of the direct costs (15-30% when profit is added), but its fee may rise to as high as fifty percent (including profit) with closure contracts.

Only rarely would a general contractor be hired to administer post-closure activities. It is more likely for an engineering firm to manage the post-closure care and hire subcontractors to perform certain maintenance activities (e.g., cover maintenance, erosion damage repair, etc.) during the post-closure period.

10.4 CONTINGENCY FEE

A contingency is added to cost estimates to compensate for errors of omission, particularly in the conceptual stage of the cost estimate, and for unforseeable circumstances. The failure to include items, generally minor, but cumulatively significant may account for approximately ten percent of the fixed capital investment during the conceptual stage of estimation. Unforseen circumstances include such things as storms, floods, fires, unanticipated price changes, unproductive labor, strikes, and design modifications and are covered by the contingency fee.

The contingency fee varies from two to thirty percent of the direct plus indirect capital cost of closure or post-closure. The contingency is highest in the early, conceptual stage of project planning and decreases as plans become more finalized, with firm cost estimates. These fees may vary as follows:

- conceptual stage 10 - 30%
- drawings, but incomplete 5 - 15%
- final plans, with bids 2 - 3%

Exceptions to this general scheme are alteration and repair projects, where a twenty percent contingency is recommended even in the final design stages, and projects with a high degree of risk, such as closure activities, where higher contingency fees are allocated to cover unexpected site conditions, contamination, or changes in the closure plan.

Closure and post-closure plans should be considered at the conceptual planning stage even if detailed plans, specifications, and drawings have been prepared. This is due to the high degree of risk and uncertainty associated with many facility closures. Consequently, the contingency fee should vary from ten to thirty percent depending on the complexity of the closure and post-closure activities and the length of time needed to complete these activities.

Table 10-1 presents typical closure and post-closure contingency fees for use on the summary worksheets if information on these fees in not provided in the closure or post-closure plan. They reflect both the complexity of the closure and post-closure activities and the relative lengths of time needed for closure. The contingency fees in Table 10-1 are for facilities at which there is no existing soil contamination. Contingency fees at sites with known soil contamination can be as high as 200 percent.

TABLE 10-1. TYPICAL CLOSURE AND POST-CLOSURE CONTINGENCY FEES

Facility Type	Closure (%)	Post-Closure (%)
Container Storage	10	--
Incinerator	15	--
Treatment or Storage Tank	15	10*
Waste Pile	15	10*
Land Treatment	20	10
Surface Impoundment	25	15*
Landfill	25	15
Multiple Process Facility	25	15*

* If post-closure monitoring and maintenance are required

APPENDIX A

- Conversion Factors and Densities
- Labor and Materials Indexes by Region
- Cost Updating Methodology
- Sources of Cost Information

APPENDIX A

A.1 CONVERSION FACTORS AND DENSITIES

This section contains conversion factors (Table A-1) and densities (Table A-2). These can be used in changing the units of an item given in a facility's Part B application to the units required on the unit cost worksheets, or in changing units between worksheets. The densities listed will provide a guide to the appropriate density of a substance and should be consulted if the density for a specific substance is not known. An example using both a conversion factor and a density is shown on Table A-2.

TABLE A-1. CONVERSION FACTORS

Quantity	Equivalent Values
Mass	1 kg = 1000g = 0.001 metric ton = 2.20 lb = 35.27 oz = 1.10×10^{-3} tons
	1 lb = 16 oz = 5×10^{-4} ton = 453.59 g = 0.45359 kg
	1 ton = 2000 lb = 907.18 kg
	1 metric ton = 1000 kg = 1.10 tons
Length	1 m = 100 cm = 39.37 in = 3.28 ft = 1.094 yds = 6.219×10^{-4} mile
	1 ft = 12 in = 0.333 yds = 0.3048 m = 30.48 cm
Area	1 ft^2 = 0.111 yd^2 = 2.296×10^{-5} acres = 0.0929 m^2
	1 yd^2 = 9 ft^2 = 2.066×10^{-4} acres = 0.836 m^2
	1 acre = 4840 yd^2 = 43,560 ft^2 4046.8 m^2
	1 m^2 = 10.764 ft^2 = 1.196 yd^2 = 2.471×10^{-4} acre
Volume	1 m^3 = 1000 liters = 35.315 ft^3 = 264.17 gallons
	1 ft^3 = 7.481 gallons = 0.02832 m^3 = 28.317 liters
	1 gallon = 3.785×10^{-3} m^3 = 0.1337 ft^3 = 3.785 liters

TABLE A-2. ESTIMATED DENSITIES OF VARIOUS MATERIALS

Material	Density
Incinerator ash	35 - 50 lb/ft^3
Demolition rubble	90 - 120 lb/ft^3
Liquids	45 - 110 lb/ft^3 = 6 - 15 lb/gal
Decontamination residue	60 - 80 lb/ft^3 = 8 - 11 lb/gal
Sludge	60 - 90 lb/ft^3 = 8 - 12 lb/gal
Soil	75 - 120 lb/ft^3
Solids	60 - 250 lb/ft^3
Water	62.4 lb/ft^3 = 8.34 lb/gal

Example:

To convert 1 ton of soil to ft^3 of soil,

1 ton soil x 2000 lbs/ton - density of soil in lb/ft^3

A.2 LABOR AND MATERIALS INDEXES BY REGION

An important element of the closure and post-closure cost estimates is the selection of accurate unit costs for the variety of site work and labor activities performed. The unit costs (and prices) developed for this document represent average costs and prices in major cities of the United States for materials and services required for site work under normal site conditions. For many construction projects, however, adverse or unusual site conditions are encountered. This is particularly evident in hazardous waste facility construction, closure, and post-closure. Unit costs for such closure activities as inventory disposal, excavation of contaminated soils, clay cover construction, and topsoil placement vary considerably among closure cost estimates submitted by TSDF owners and operators.

Variations in unit costs are primarily the result of regional differences in material and labor rates and whether required materials are available on-site or must be purchased and transported from an off-site source. Other factors which affect unit and project costs significantly are weather, season of year, site topography, soil type, job size, safety requirements, site accessibility, travel time, equipment availability, building code and permit requirements, availability of utilities, and presence of a skilled labor force. Local or regional shortages of construction materials can also significantly influence unit costs. It is possible, however, to apply construction cost indexes for various cities to incorporate labor and material cost characteristics inherent to specific locations. For instance, variations in wage rates, labor efficiency, union restrictions, and material prices will result in regional differences that can be factored into a cost estimate by using appropriate construction indexes. An example of city indexes for each EPA Regional Office is provided in Table A-3. The city indexes, prepared from data for 162 major U.S. and Canadian cities by R.S. Means for both materials and installation, are based on the 30 major city average of 100 and represent the cost relationship as of July 1, 1985. Table A-3 also reports a factor, derived from the "total" index, that can be used to quickly index a cost estimate to a particular EPA Regional Office. This is accomplished by multiplying the closure or post-closure cost estimate from the summary worksheet (prior to applying the engineering fee, contractor's overhead and profit, and contingency factor) by the Regional city cost factor listed in the table.

TABLE A-3. 1986 CITY COST INDEXES

EPA Region	City	Index Material	Index Installation	Index Total	Index Factor
1	Boston	109.8	99.9	105.3	1.05
2	New York	119.4	115.1	117.5	1.18
3	Philadelphia	102.3	106.8	104.3	1.04
4	Atlanta	101.9	91.5	97.2	0.97
5	Chicago	100.4	103.2	101.6	1.02
6	Dallas	115.4	90.0	103.9	1.04
7	Kansas City	92.2	104.4	97.7	0.98
8	Denver	103.4	104.9	104.1	1.04
9	San Francisco	103.1	113.9	108.0	1.08
10	Seattle	103.1	100.7	102.0	1.02

A.3 COST UPDATING METHODOLOGY

All of the costs reported in this unit cost guidance document are 1986 costs. In subsequent years the various unit costs will increase or decrease, changing the resultant total closure and post-closure costs. During the active life of the facility, the owner or operator must adjust the closure and post-closure cost estimates for inflation within 60 days prior to the anniversary date of the establishment of their financial instruments (within 30 days after the close of the firm's fiscal year for firms using the financial test or corporate guarantee). This adjustment may be made by recalculating the costs of closure or post-closure in current dollars (a very time-consuming process), or by using an inflation factor derived from the most recent Implicit Price Deflator for Gross National Product published by the U.S. Department of Commerce in its Survey of Current Business. The inflation factor is the result of dividing the latest published annual Deflator by the Deflator for the previous year. For example, assume that the latest closure cost estimate is $50,000; the latest published annual Deflator is 111.7 (1985); and the annual Deflator for the previous year (1984) is 108.1. Dividing 111.7 by 108.1 gives the inflation factor, 1.03. Multiplying $50,000 by 1.03 gives a result of $51,500, the adjusted closure cost estimate.

To update a specific unit cost used in the calculation of closure or post-closure costs, the Builders' Construction Cost Indexes are recommended and available in quarterly "cost roundup" issues of the journal Engineering News Record (ENR). The two general-purpose cost indexes we suggest using are the "ENR 20-Cities: Construction Cost," or the "Means: Construction Cost." Their January 1986 values are 392 and 356, respectively. By using these indexes, unit costs can be updated quarterly, biannually, or annually. To update a unit cost, look up the value corresponding to the new date (e.g., January 1986) in either cost index, divide the new value by the 1985 value and multiply the resulting factor by the original unit cost to arrive at a new (updated) unit cost.

A.4 SOURCES OF COST INFORMATION

Building Construction Cost Data 1986, Robert Snow Means Co., Inc., 1985. Unit costs are provided for the labor, materials, and installation components of many types of construction projects. City cost indexes, historical indexes, and equipment rental costs are also included. $34.95 (R.S. Means Co., Inc., 100 Construction Plaza, P.O. Box 800, Kingston, MA 02364-9988).

Chemical Engineering, McGraw-Hill, New York, bi-weekly perodical. Cost file section provides various information useful for cost engineering estimation. Economic indicators are published bi-weekly which include several construction and equipment cost indices. $24.50 per year (tel. 609-786-0836).

Construction Estimating Reference Data, Craftsman Book Co., Carlsbad, California, 1984. Provides labor requirements for all types of construction, explaining in detail the work being estimated, the appropriate crew size, and equipment needed. $18.00 (tel. 619-438-7828).

Cost Engineering Analysis, William R. Park, Wiley-Interscience, New York, 1973. A guide to economic evaluation of engineering projects. Topics include depreciation, the cost of capital, estimation of capital and operating costs, and equivalent annual costs.

1985 Dodge Guide to Public Works and Heavy Construction Costs, McGraw-Hill, New York, 1984. Provides cost data for construction site work, maintenance, and equipment rental. Also includes city cost adjustment indexes, historical cost indexes, and useful reference table. $48.50 (Cost Information Systems, McGraw-Hill Information Systems Co., P.O. Box 28, Princeton, New Jersey, 88540).

Engineering Economics, James L. Riggs, McGraw-Hill, New York, 1982. Principles of estimating and forecasting, economic analyses, and engineering decisions in an economic framework are covered in detail.

Engineering Economy, Leland Blank and Anthony Tarquin, McGraw-Hill, New York, 1983. Includes discussions on depreciation methods, costing analysis, capitalized and annualized cost evaluation, and sensitivity and risk analysis.

Engineering News-Record, McGraw-Hill, New York, weekly periodical. Construction economics section gives up-to-date information on materials prices, unit prices, market trends, and cost indexes. Quarterly issues provide unit cost and market trend summaries and historical cost indexes. $38.00 per year (tel. 914-628-3769).

Innovative and Alternative Technology Assessment Manual, U.S. EPA 430/9-78-009, February 1980. Provides cost curves for a variety of treatment technologies, and presents a methodology for the development of capital costs.

Means Site Work Cost Data 1986, Robert Snow Means Co., Inc., 1985. Unit costs are presented for the labor, materials and installation components of site work. City cost indexes, historical indexes, and equipment rental costs are also included. $36.95 (R.S. Means Co., Inc., 100 Construction Plaza, P.O. Box 800, Kingston, MA 02364-9988).

National Construction Estimator 1986, Craftsman Book Co., Carlsbad, California, 1985. Provides current costs for residential, commercial, and industrial construction, including materials and the proper installation labor cost. $16.00 (tel. 619-438-7828).

Perry's Chemical Engineering Handbook, 6th edition, McGraw-Hill, New York, 1984. Includes sections on waste management, transportation and storage of bulk solids and liquids, process economics, manufacturing-cost estimation, and fixed capital cost estimation.

Process Plant and Equipment Cost Estimation, Craftsman Book Co., Carlsbad, California, 1984. Current cost data and estimating methods for process plant construction. Includes labor costs and productivities, the cost of chemicals, materials, and utilities, location cost indexes, and operating costs. $19.00 (tel. 619-438-7828).

The Richardson General Construction Estimating Standards, 3 vols., Richardson Engineering Services, Inc., San Marcos, California, 1984. Comprehensive cost estimating system for sitework and general construction activities. $147.00 (tel. 619-489-5806).

The Richardson Process Plant Construction Estimating Standards, 4 vols., Richardson Engineering Services, Inc., San Marcos, California, 1984. Comprehensive cost estimating system for chemical plants, manufacturing facilities, solids processing, water treatment plants, general construction projects and buildings. $345.00 (tel. 619-489-5806).

A Standard Procedure for Cost Analysis of Pollution Control Operations, 2 vols., U.S. EPA 600/8-79-018a and -018b, June 1979. Sets forth a standard procedure for preparing engineering cost analyses, including capital investment and annual expense estimates, discrete and continuous interest factors, and cost indices and inflation factors.

1985 Thomas Register of American Manufacturers and Thomas Register Catalog File, 18 vols., Thomas Publishing Company, New York, 1985. Provides a comprehensive list of vendors arranged by products and services offered, company profiles, and company catalogs. $175.00 (tel. 212-290-7277).